
Fractus Technology Tutorial
Fractus, S.A. v. AT&T Mobility LLC, et al., 2:18-CV-00135-JRG
Fractus, S.A. v. Sprint Communications Company, et al. 2:18-cv-00136-JRG
Fractus, S.A. v. T-Mobile US, Inc. et al., 2:18-cv-00137
Fractus, S.A. v. Verizon Communications Inc., et al., 2:18-cv-00138-JRG
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Fractus Technology Tutorial: Outline

- Introduction to Fractus
- Technical background regarding electromagnetic waves, wireless communications and antennas
- The multiband base station antenna technology of the interlaced and slim triple band patents-in-suit

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Fractus presents this tutorial to familiarize the Court with the Fractus technology at issue in this case.

The tutorial has three sections:

The first section is a brief introduction to Fractus.

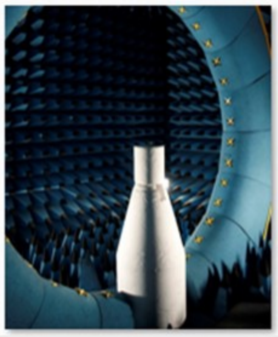
The second section includes a technical background about electromagnetic waves, wireless communications, and antennas.

The third section describes the interlaced and slim triple band antenna technology that is the focus of the patents-in-suit.

Fractus

Fractus

- Over 120 patents and patent applications in US, Europe, Asia and Latin America
- 50 million antennas
- Over 1000 clients worldwide
- 50+ countries



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Fractus is a technology company based in Barcelona, Spain. It was founded in 1999 by Dr. Carles Puente, the primary inventor, and Ruben Bonet, the CEO.

The company holds an intellectual property rights portfolio of more than 120 patents and patent applications in the United States, Europe, Asia and Latin America.

Fractus has sold over 50 million antennas to more than 1000 companies in over 50 countries.

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Fractus multiband antenna technology

- Fractus is a pioneer in the development of **multiband antenna technology.**
- Fractus' inventions **increase antenna performance, reduce antenna size**, and **optimize multiband functionality.**
- These innovations allow cellular carriers to **provide services to a larger number of customers**, **offer a wider range of services**, **improve coverage and save costs.**

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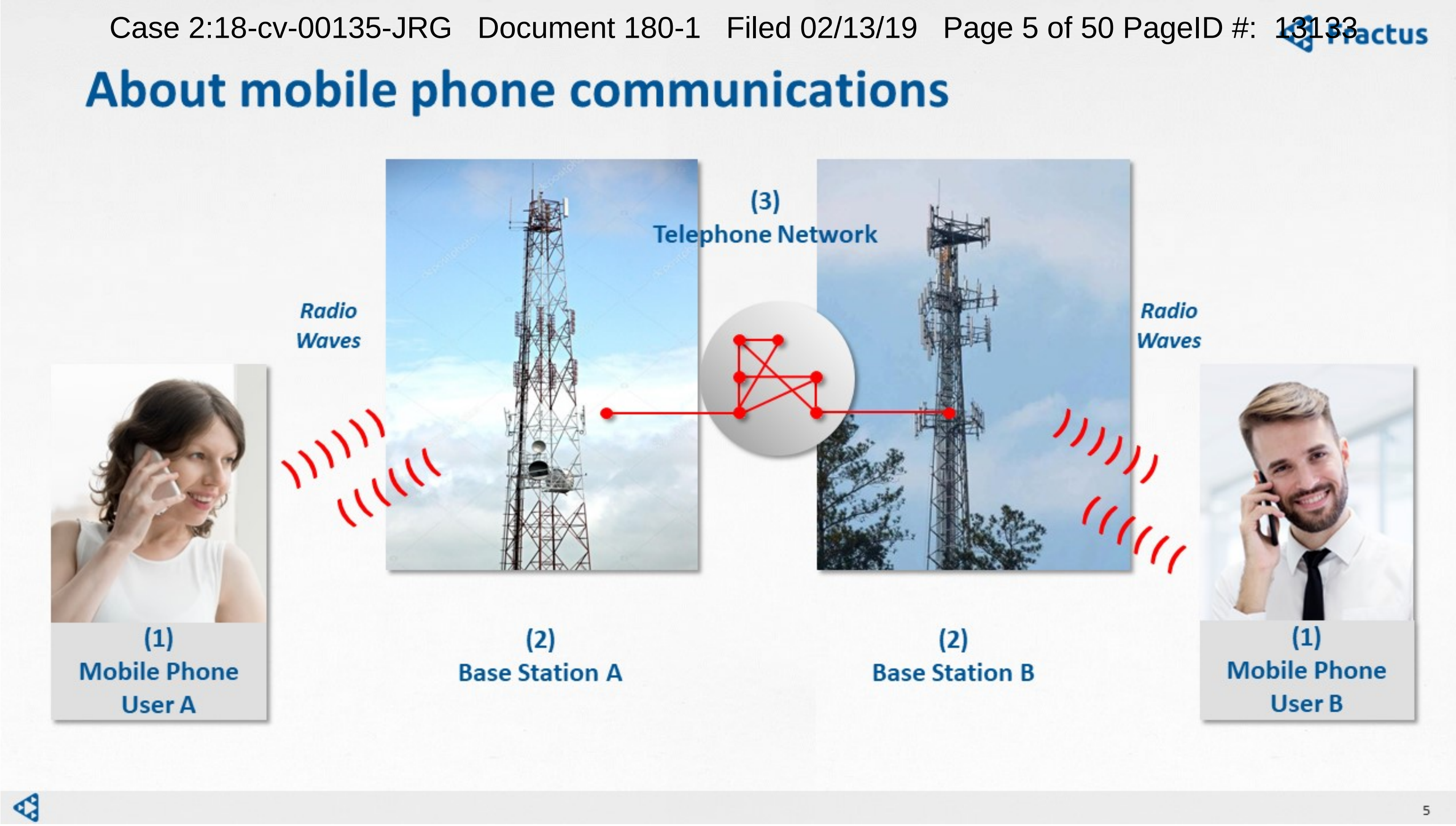
Fractus is a pioneer in the development of multiband antenna technology.

Fractus's inventions increase antenna performance, reduce antenna size, and optimize multiband functionality.

These innovations allow cellular carriers to provide services to a larger number of customers, offer a wider range of services, improve coverage and save costs.

Before explaining Fractus's base station antenna inventions, we will briefly review some background about antenna technology.



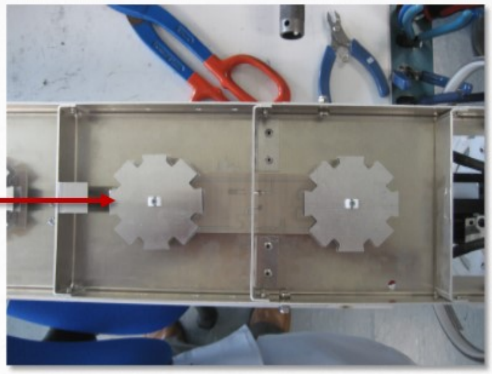
There are three major physical components involved in cellular communications: (1) mobile phones, (2) base stations, and (3) a telephone network.

Mobile phones communicate with base stations through radio waves. Every base station uses one or more antennas through which radio waves are sent and received. Such antennas are common sights on towers found alongside highways or mounted on buildings in urban environments.

Cellular base station antennas

- Cellular base station antennas are made up of **multiple individual antennas that work together** to receive or radiate radio waves.
- That combination of elements is known as an "**array**," and allows the base station antenna to transmit and receive more efficiently and effectively in the desired direction.
- Each of the individual antennas in an array is called an "antenna element" or "**element**."

Antenna element



Antenna array

Cellular base station antennas are made up of multiple individual antennas that work together to receive or radiate radio waves.

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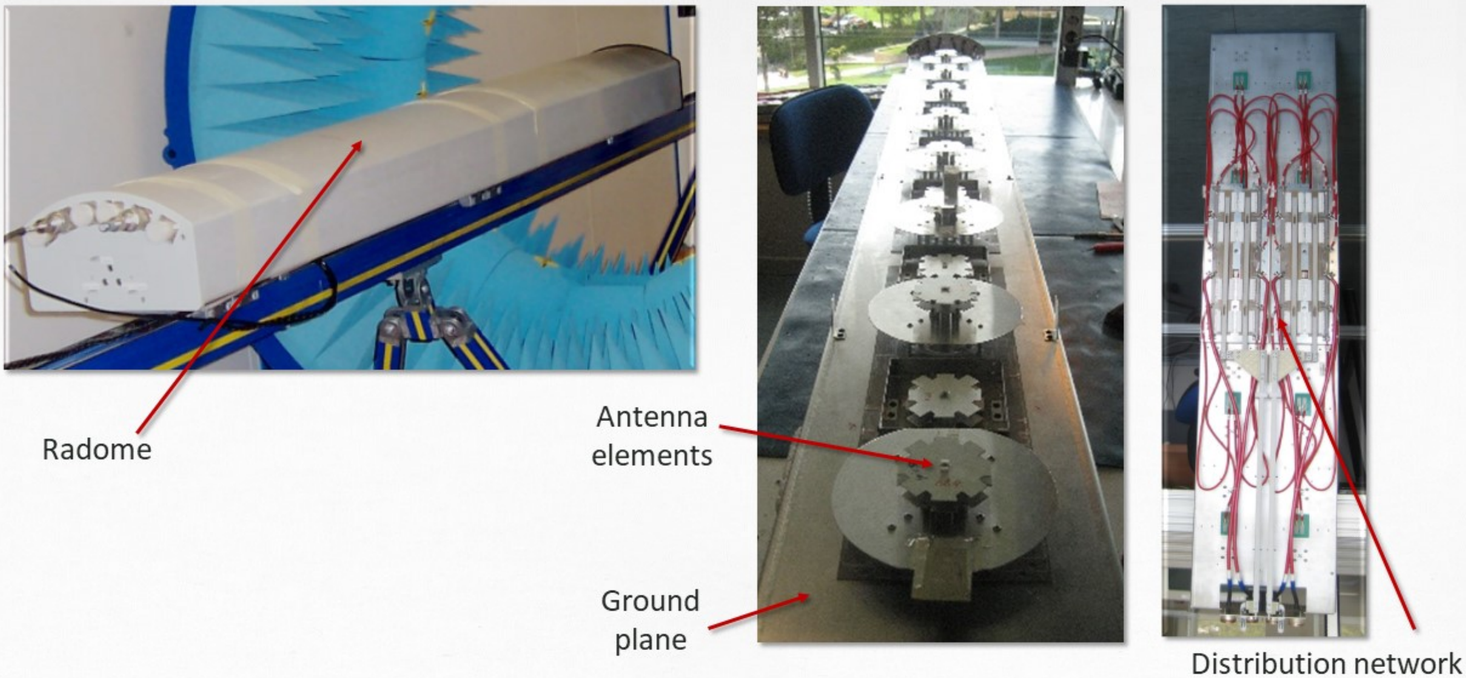
Cellular base station antennas



On the left here, a base station array is shown with its protective cover, or radome.

In the middle photograph, the radome has been removed to show the antenna elements that make up the array. The elements are arranged on what is called a “ground plane.”

The photograph on the right shows the backside of the array, behind the ground plane. Shown here is the wiring that feeds the elements, known as a “distribution network.”

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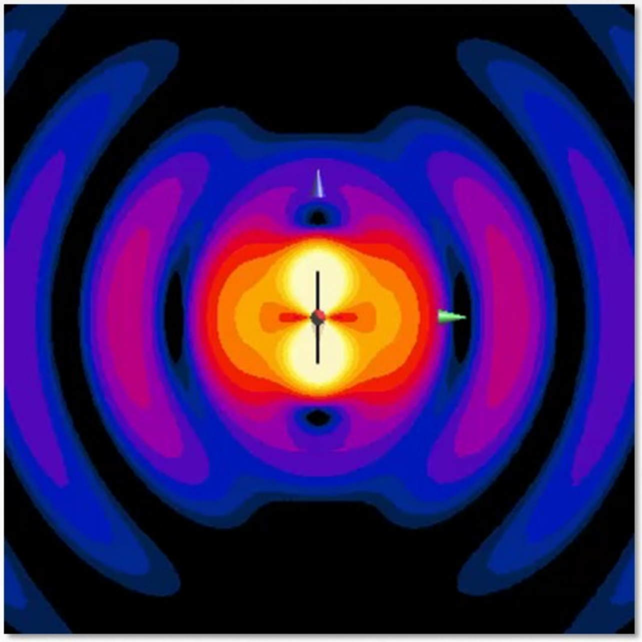
Antenna basics



To understand Fractus's base station antenna arrays, it is helpful to start with a basic understanding of antennas and how they operate.

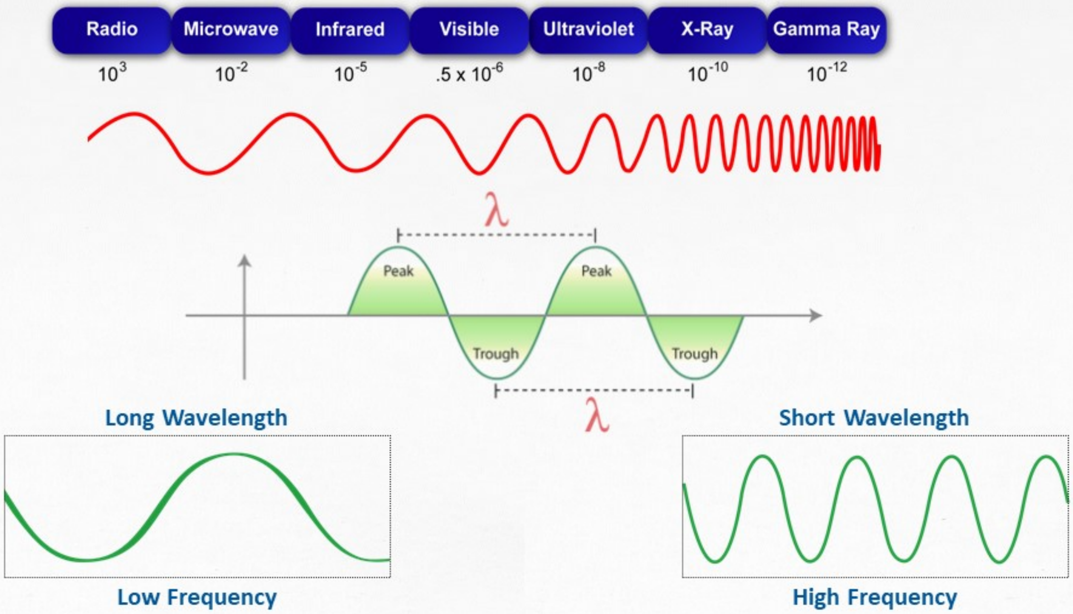
An antenna as a part of a transmitter or receiver system which is designed to receive and/or radiate electromagnetic waves.

This engineering model shows a dipole emitting radio waves.

Electrical current is travelling on the antenna, as indicated by the white and yellow coloring on these components.

This results in the generation of radio waves, which can be seen emanating from the antenna and travelling through space.

Electromagnetic Waves



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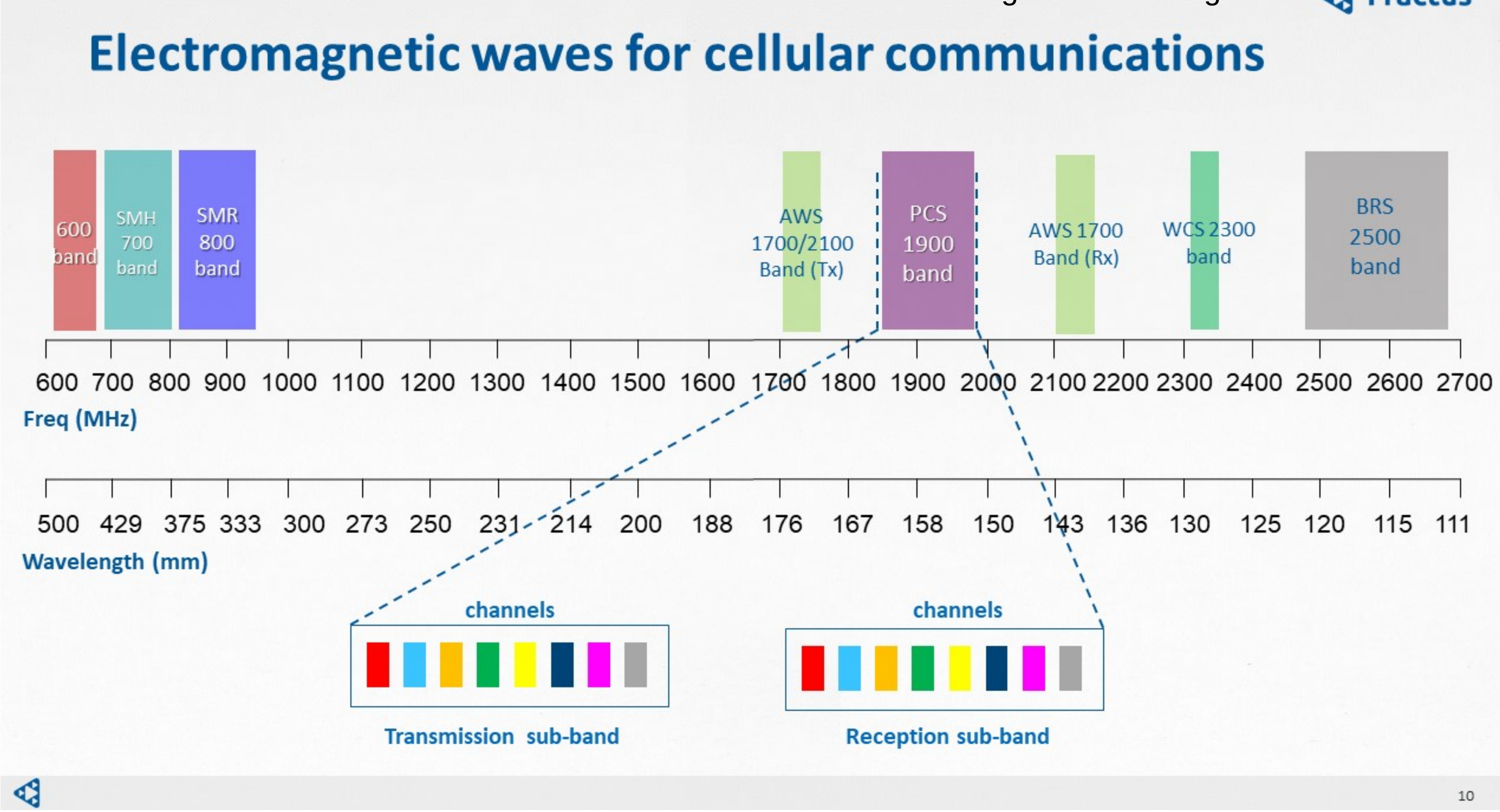
Radio waves are a type of electromagnetic wave. Radio waves are defined by their wavelength.

The wavelength is the distance between two matching points on a wave, which is measured in meters. For example, this could be the distance between two peaks, or two troughs of a wave.

As shown in these graphics, the shorter the wavelength, the higher the frequency. Conversely, the longer the wavelength, the lower the frequency. Accordingly, as the wavelength increases, the frequency decreases, and vice versa—in other words, they are inversely proportional



Electromagnetic waves for cellular communication are typically within the 600 to 2700 Megahertz range, meaning that they have a wavelength between approximately 500 and 111 millimeters.

Certain radio frequencies have been designated for a cellular service. Such designated ranges are known as a frequency band, and are used in that specific way in the patents-in-suit.

Each band is subdivided into both transmission and reception sub-bands, so a mobile phone or base station can both receive and transmit electromagnetic waves within a single frequency band.

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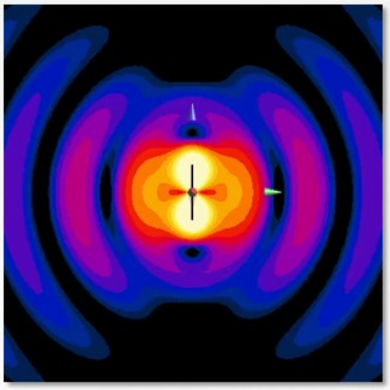
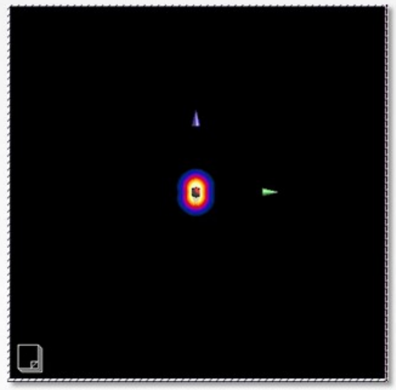
Antenna size and radiation



1/2 wavelength = 15 cm



1/10 wavelength = 3 cm

1000 MHz = Frequency
30 cm = wavelength

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There is a relationship between the size and shape of an antenna and the wavelengths at which it can transmit and receive. Take for example a simple wire dipole antenna like the one shown here. In order for the antenna to transmit and receive waves effectively, it typically needs to be about half or a quarter of a desired wavelength.

This engineering model shows the relationship between antenna size and radiation for such antenna.

The antenna on the left has a size equal to half a wavelength. The antenna on the right has a size equal to one tenth of the wavelength.

As shown by the simulation, the antenna on the left is radiating effectively, while the one on the right is not. This is because the antenna on the left has a suitable size—namely, half of the wavelength of the operating frequency, while the antenna on the right is too small.

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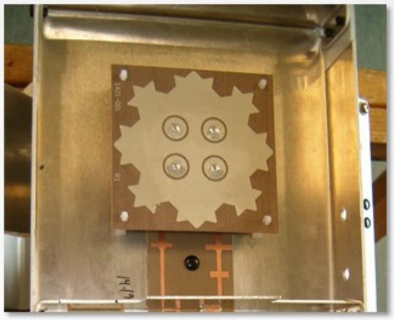
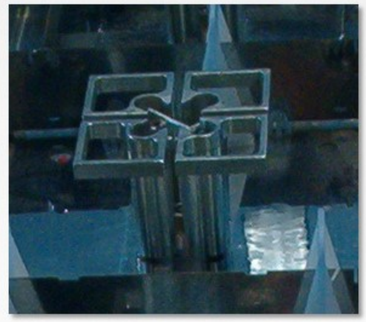
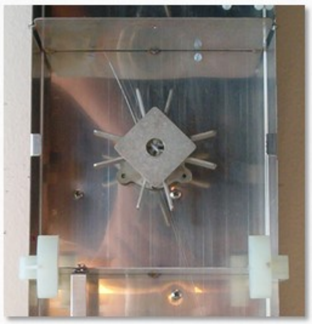
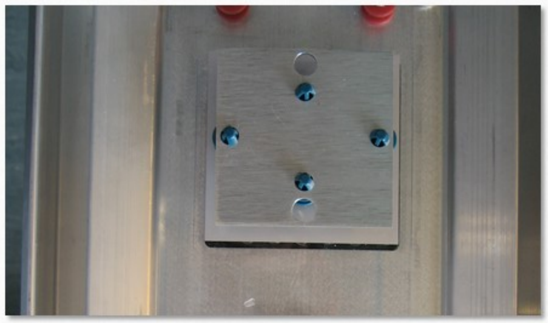
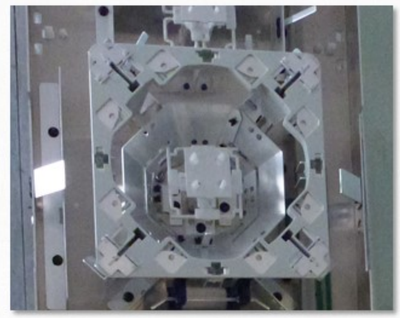
Antenna geometries







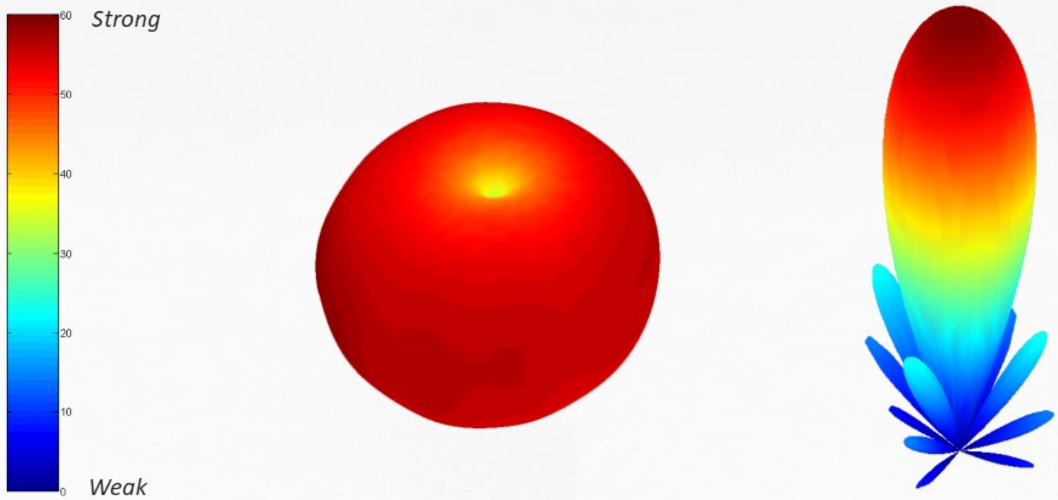




Antennas come in many different shapes, sizes, and configurations. While the example we have looked at so far is a simple dipole, many have complex geometries that contribute to their transmission and reception characteristics.

Radiation pattern

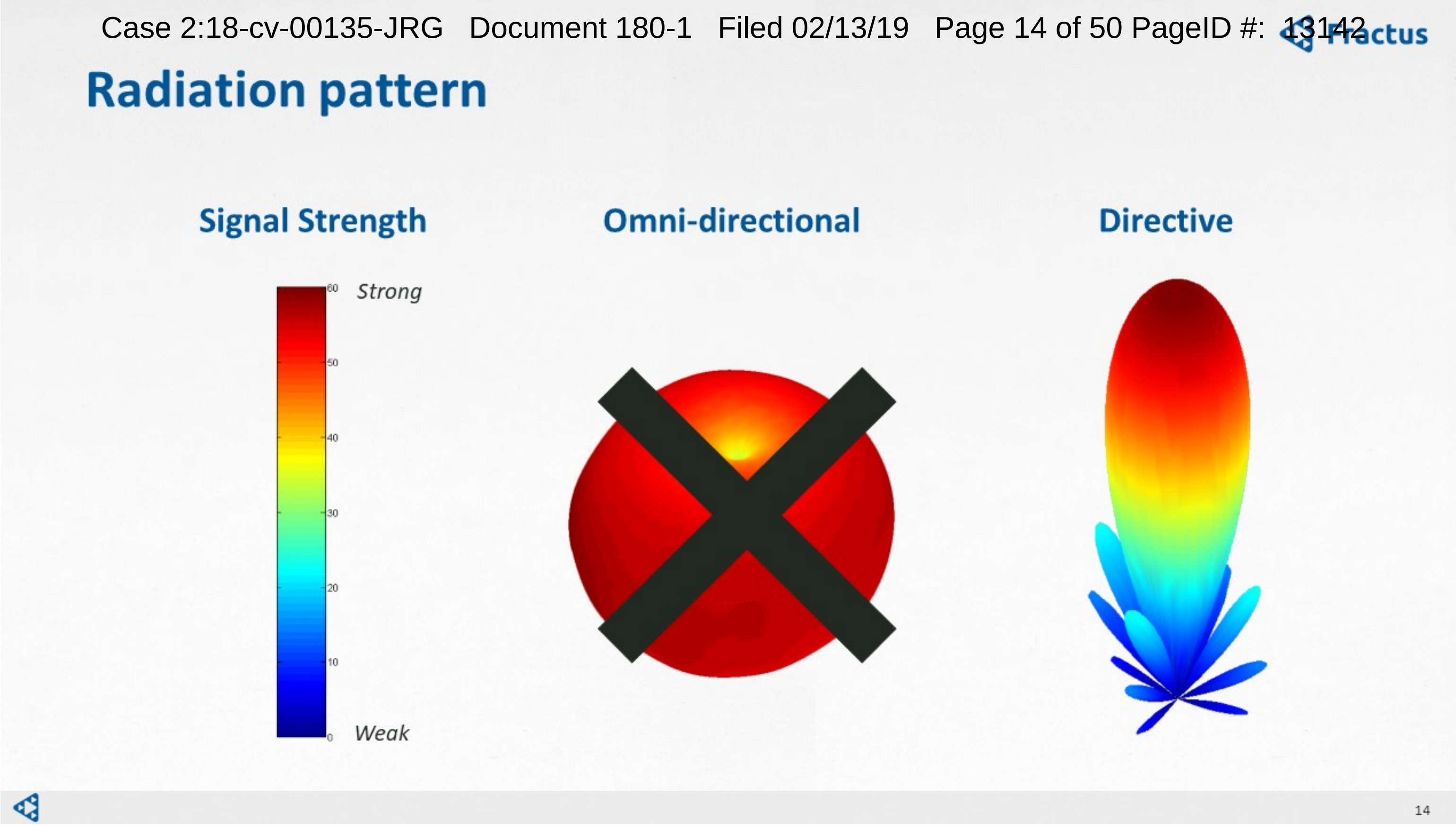
Signal Strength **Omni-directional** **Directive**



Antenna engineers use a variety of measurements to evaluate the antennas' transmission and reception characteristics. These measurements include gain, impedance and the antenna's radiation pattern. Let's look first at radiation patterns.

A radiation pattern is a three dimensional representation of how an antenna radiates the energy into space. The shape of the radiation pattern depends on the antenna geometry and configuration, two very different radiation patterns are shown here for two different types of antennas .

The radiation pattern to the left shows electromagnetic waves of similar strength in the directions around the antenna—called an "omni-directional" radiation pattern. The picture on the right shows a directive radiation pattern, or one that is stronger in one direction.

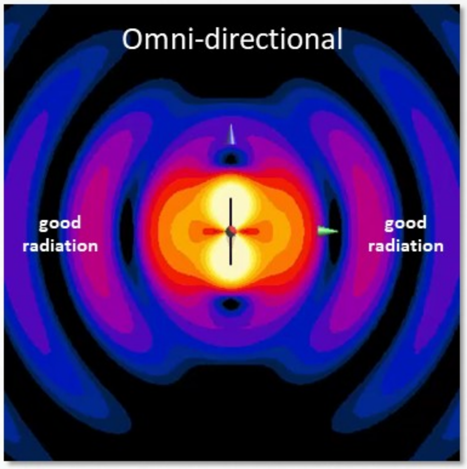


An omnidirectional antenna is appropriate for a mobile device, which may at different times be in a different position relative to the base station antenna as the user moves around.

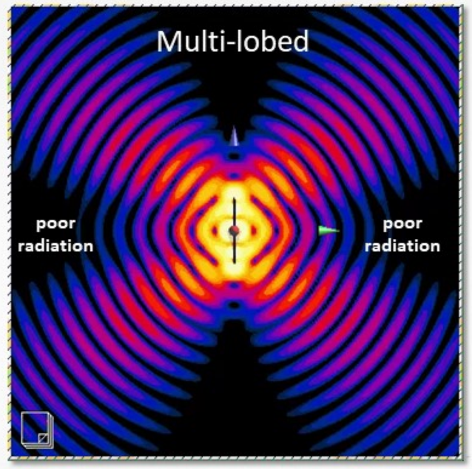
But base station antennas are designed to cover specific areas, and therefore require the use of antennas with a directive radiation pattern pointing to the area of coverage.

Radiation pattern

Relationship to antenna length and wavelength



Properly Sized Antenna
(1/2 the wavelength)



Improperly Sized Antenna
(2x the wavelength)

The radiation pattern for an antenna can be different at different frequencies. As shown here, an antenna may provide an omnidirectional radiation pattern at one frequency, but at a different frequency provide a multilobed radiation pattern with areas of no coverage in certain directions.

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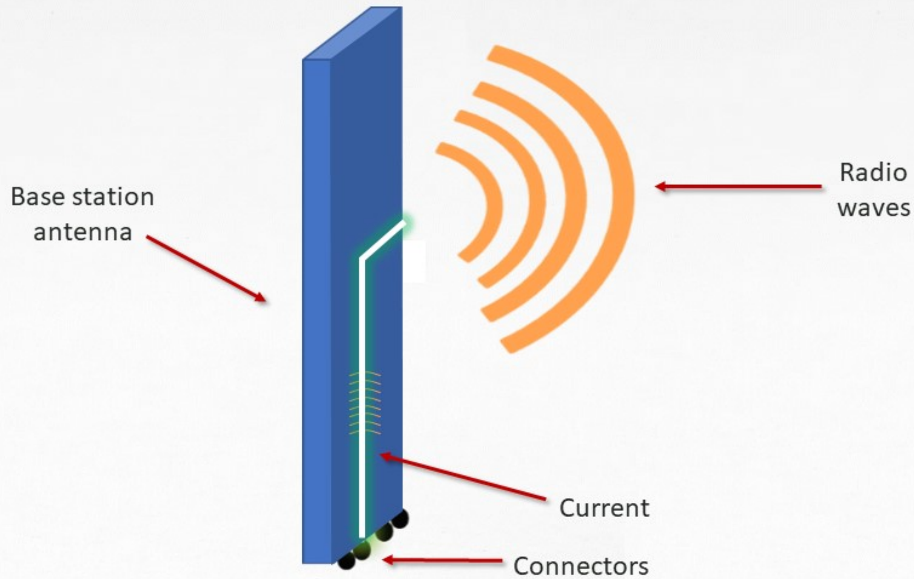
Impedance



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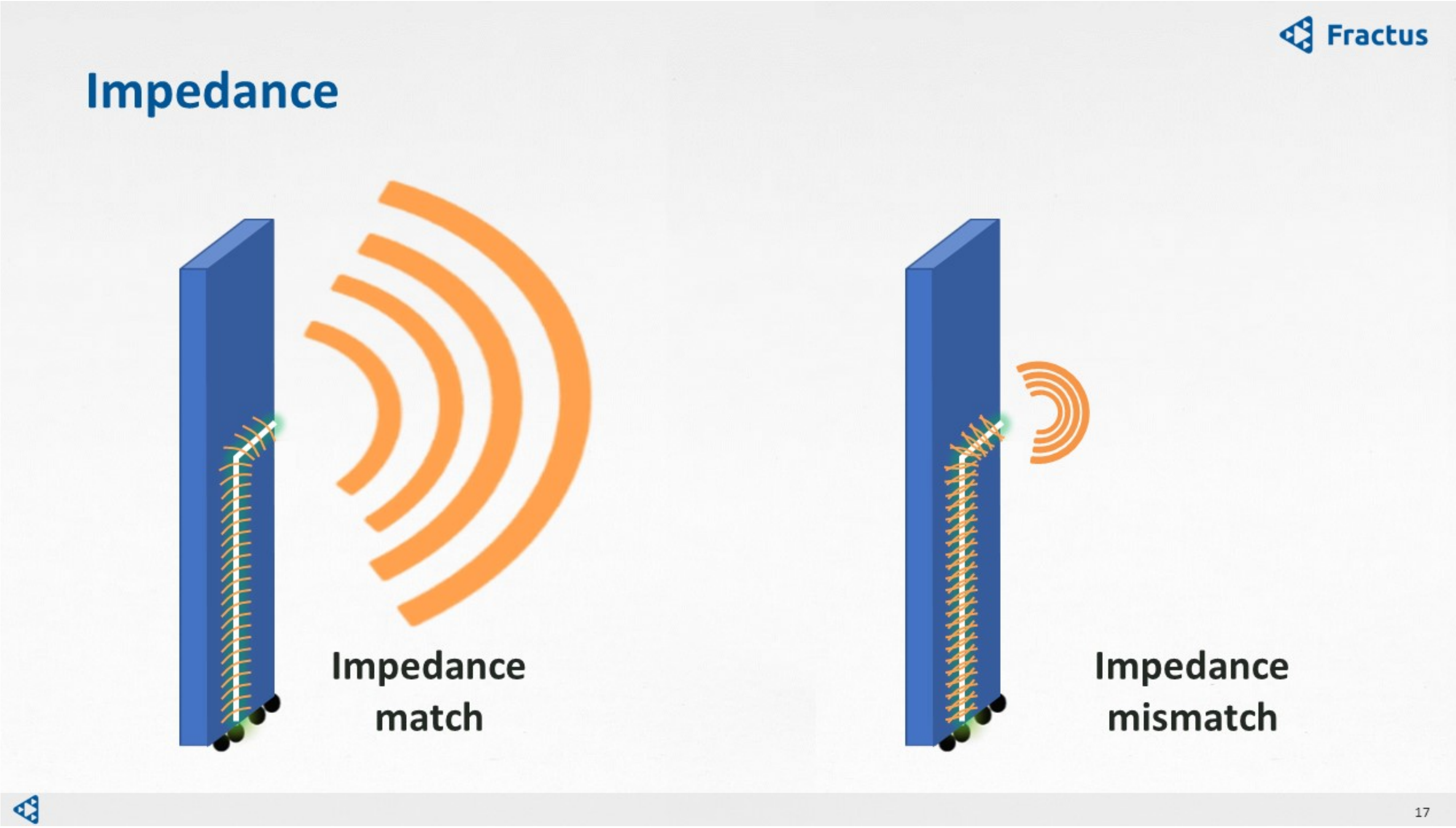
Let's look next at impedance.

Impedance measures how much of the current from the base station equipment is transferred to the antenna.

If the impedance of the antenna "matches" the impedance of the base station equipment, the antenna will radiate electromagnetic waves effectively at the required frequency band.



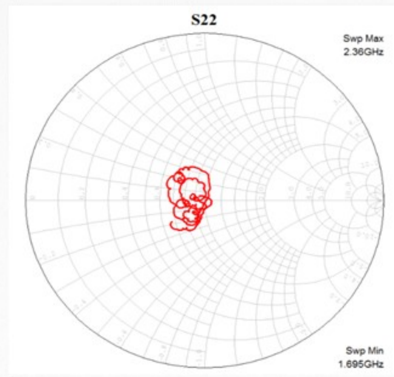
If there is an impedance "mismatch," some of the current will be reflected back towards the base station equipment.
This will result in a weaker current on the antenna, and therefore the antenna will not radiate electromagnetic waves as effectively.

The example on the left shows a good impedance match—almost all of the power of the signal coming from the base station equipment is transformed into current on the antenna, and therefore the electromagnetic waves generated by the antenna are strong.

The example on the right shows a poor impedance match—a large amount of the signal is reflected, and therefore very little of the power from the base station equipment is transformed into current on the antenna. As a result, the electromagnetic waves are quite weak, or non-existent.

Impedance

- Antenna engineers can measure or simulate the impedance at various frequencies to determine if the antenna is properly matched at the desired working frequencies.
- The results of the measured impedance is shown here, which is represented in two different ways, showing the pattern of the impedance for a particular antenna model at different frequencies.



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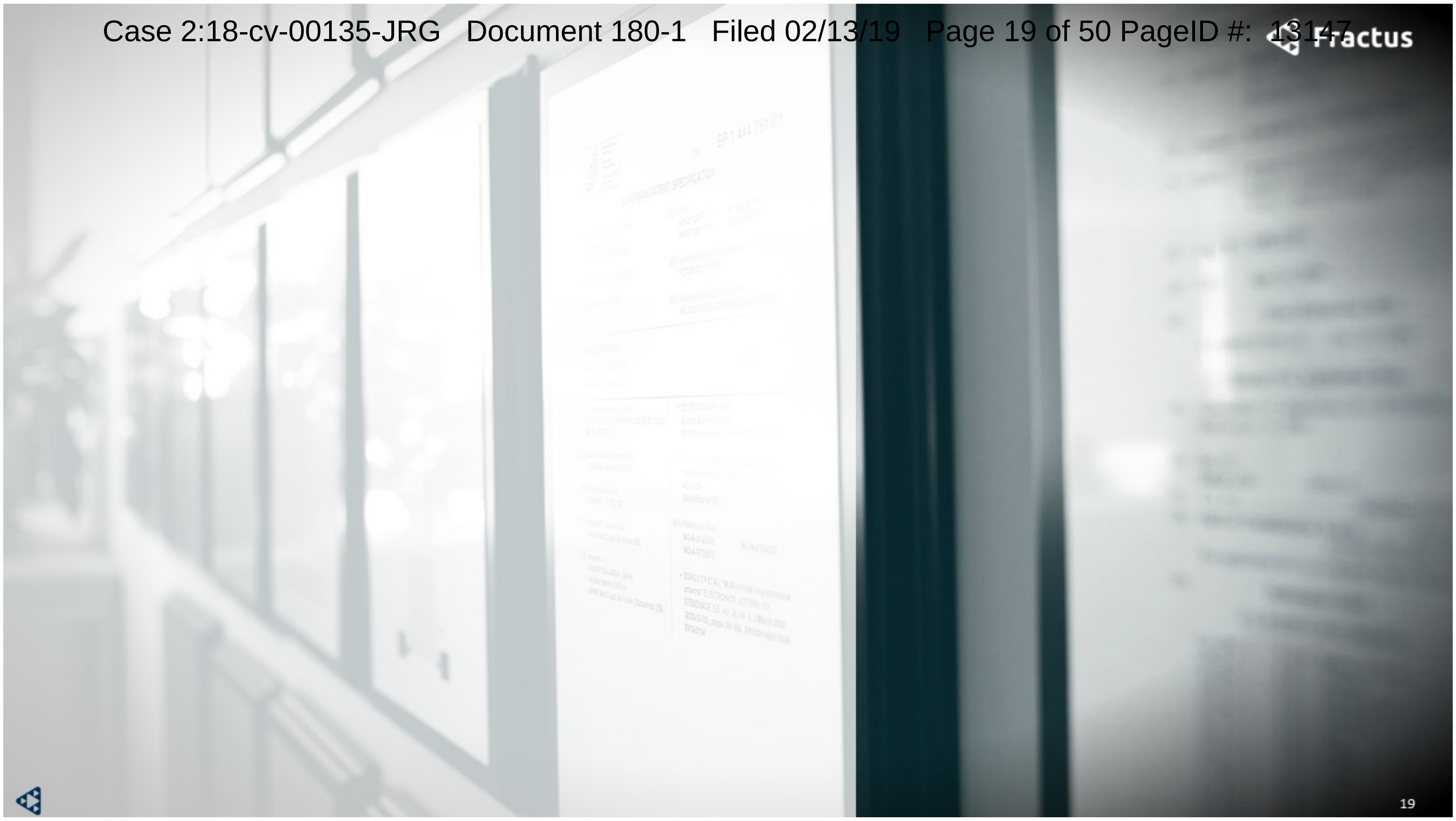
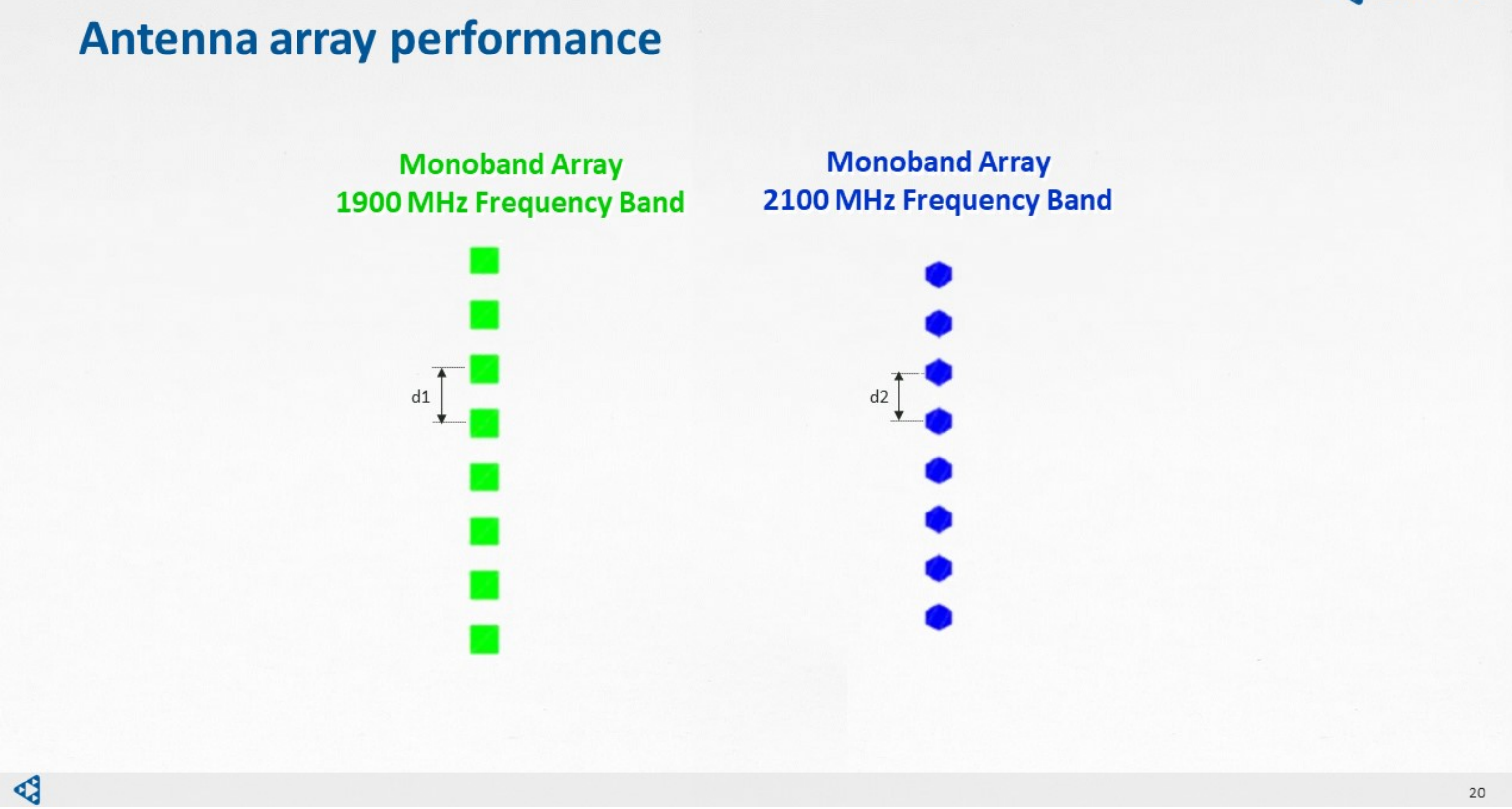
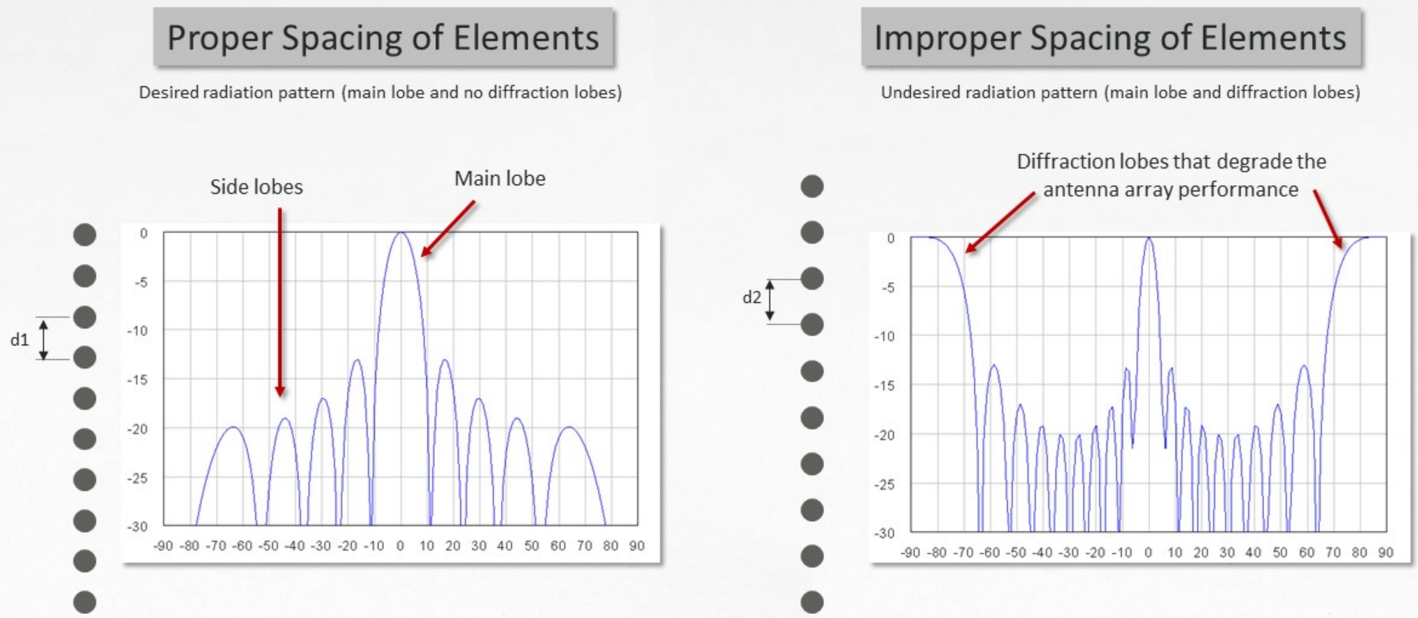


We will now look at Fractus' patented base station antennas.



The performance of an antenna array is determined by a variety of factors, including the size and geometry of the individual antenna elements that make up the array and the spacing between the elements.

Antenna array performance



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Unlike omnidirectional antennas used for mobile devices, base station antennas are designed to cover a particular area in a given direction. To determine how well the array radiates in a particular direction, we can look at the antenna's radiation pattern. In particular, we plot a cut of the radiation pattern corresponding to the vertical plane (or the direction along the array length).

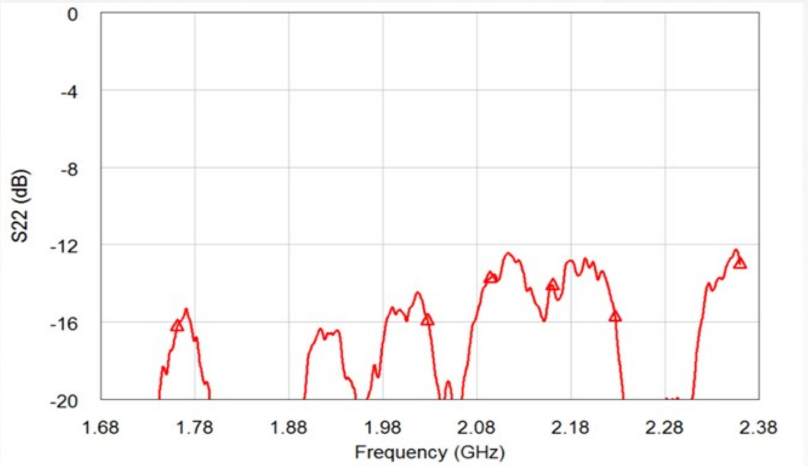
In an array, the radiation pattern is determined in part by the spacing of the antenna elements. Prior to the Fractus invention, arrays covering a single band were in common use.

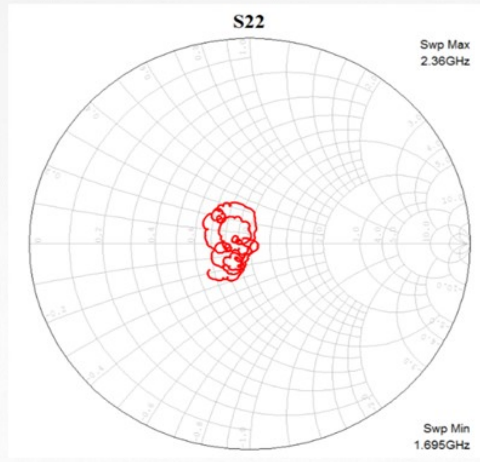
Antenna engineers understood that the spacing of the elements in such arrays should be around half a wavelength, but never more than one wavelength, in order to avoid an undesirable radiation pattern—in particular, diffraction or grating lobes that did not direct the electromagnetic waves to the right area.

In the desirable radiation pattern shown on the left, the electromagnetic energy is directed in the correct direction, with little energy being wasted in diffraction or grating lobes.

In the undesirable radiation pattern shown on the right, the energy is not directed in the desired direction, but rather into diffraction or grating lobes.

Antenna array performance





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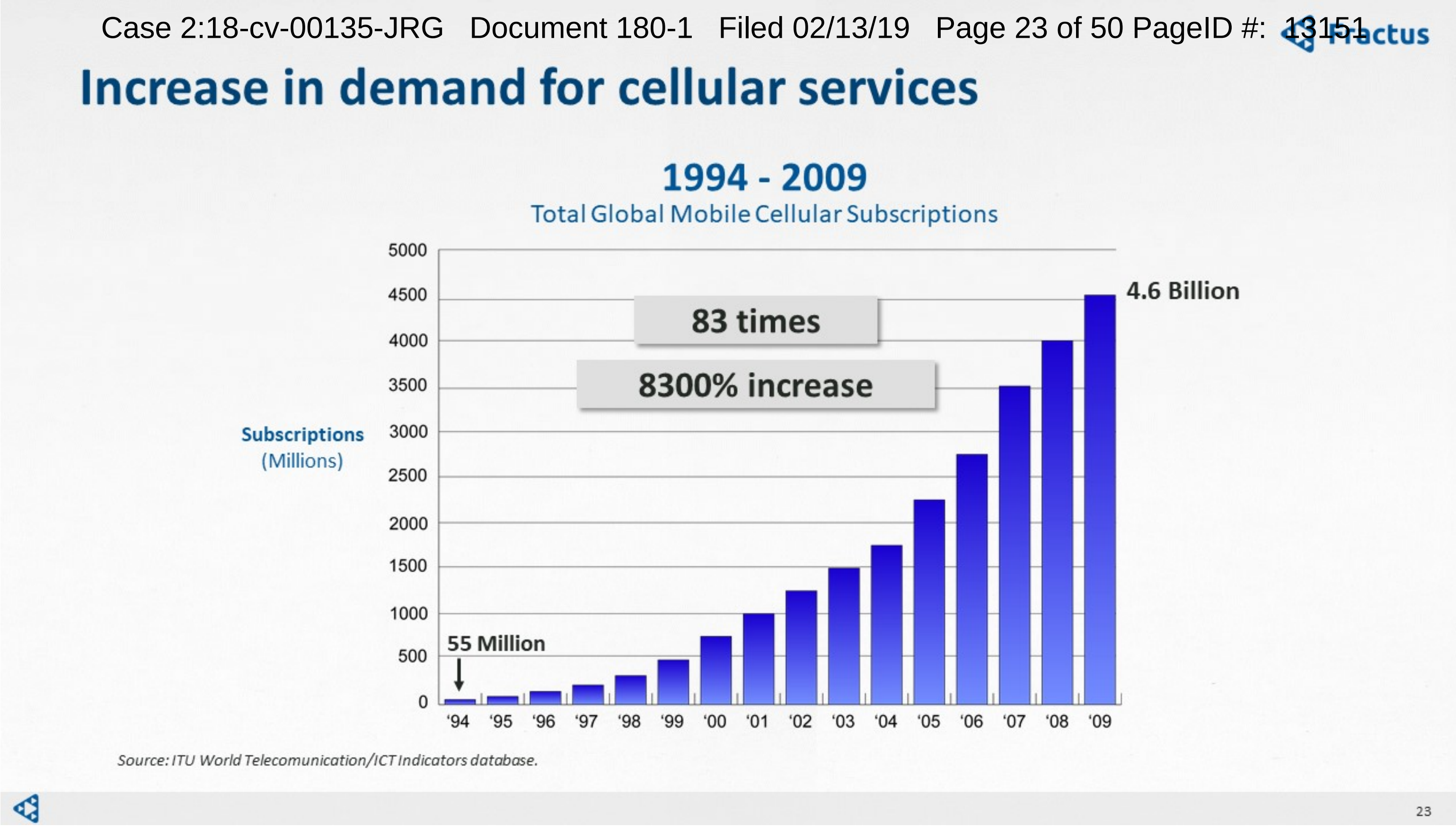
It is also important that the array utilize the correct antenna elements that are appropriately matched, including for the correct impedance and isolation at the operating frequency bands.

Again, that matching and isolation is related to the size and geometry of the antenna element.

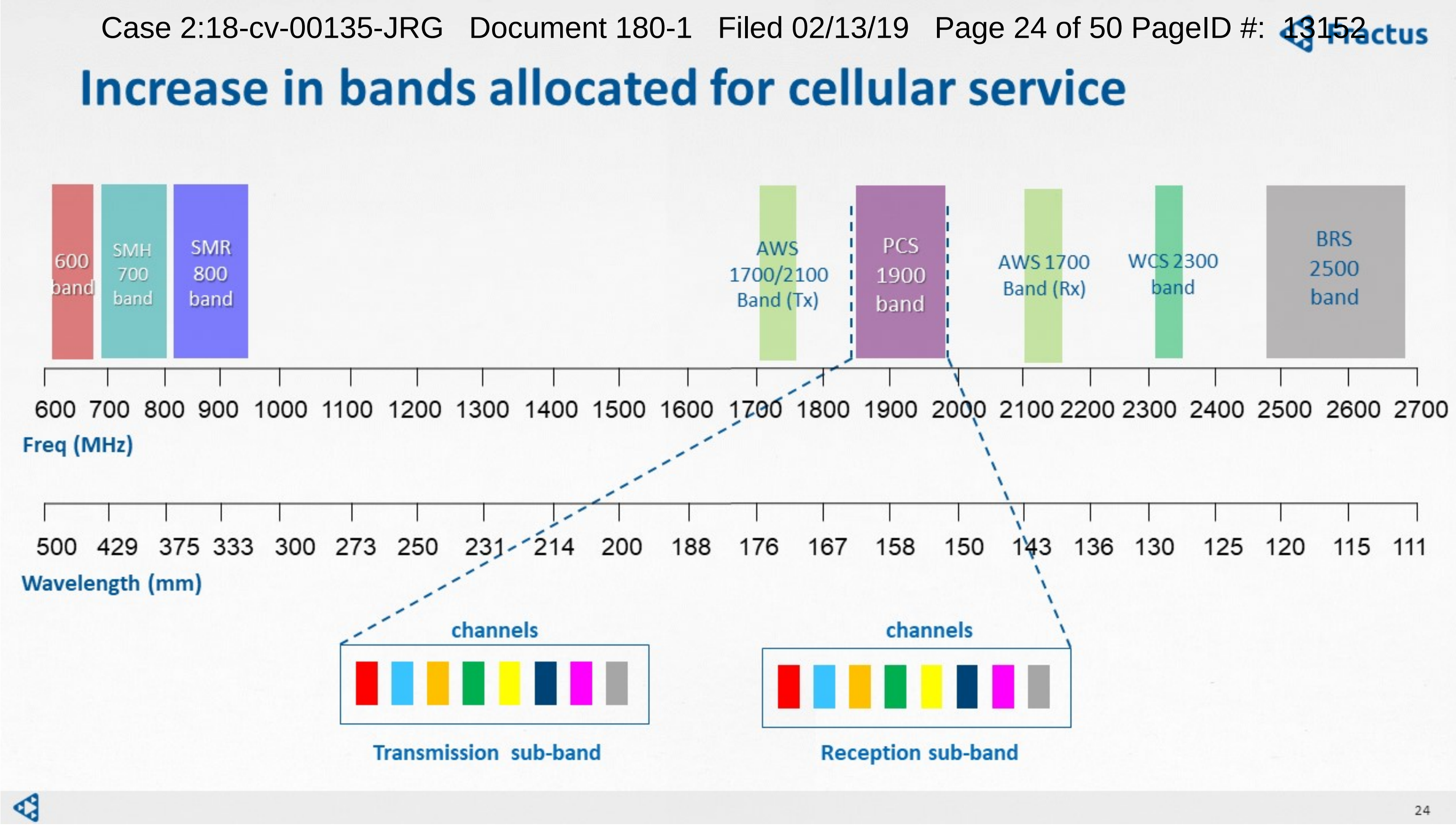


Early mobile phones all worked at a single frequency band around 850 megahertz.

Cellular network operators could build their networks using base station antenna arrays designed to operate at that single frequency band.

But during the 1990s and 2000s, the number of users or cellular subscriptions exploded, placing huge demands on the mobile network infrastructure. That demand was driven not just by the larger number of users, but on the increased use of data services by the users.

The existing frequency bands proved insufficient to meet the new demand.



Governmental agencies like the FCC responded to the increase in demand by allocating additional spectrum to cellular services.

But because much of the available spectrum was already being used for other purposes, the new spectrum was in frequency bands that were not next to the other bands that had been allocated.

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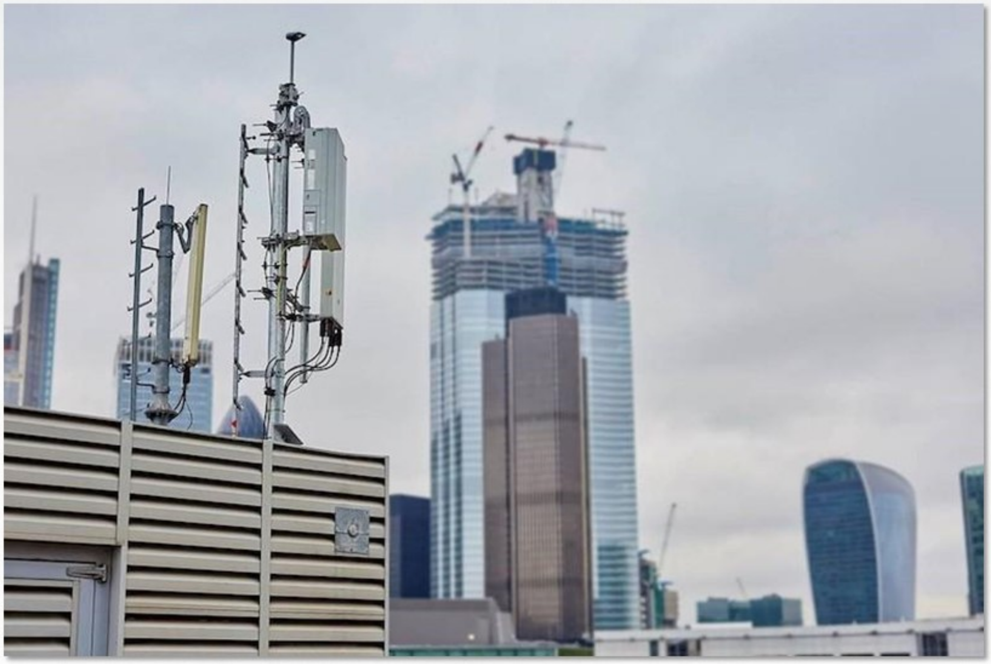
Challenges for cellular carriers



As the number of frequency bands increased, cellular network operators faced a dilemma. In order to cover the new frequency bands, they needed to deploy separate base station antennas that covered those bands.

But adding multiple antennas was very expensive, even when they were housed side-by-side under the same radome.

Not only did the carriers face additional costs for buying the antennas themselves, but the tremendous expense of space at each installation site, which are typically owned by third parties. Adding additional antennas to towers would cost the carriers billions of dollars, increasing with the deployment of third, fourth and fifth frequency bands.
And in certain locations, like urban centers, it is simply impossible to add additional antennas.

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Fractus' solution

- Fractus' inventions provided the solution to that problem, and are now used nearly universally by carriers across the United States—and the world.
- Fractus' patented base station antenna arrays allow for a **single** antenna array to operate at **multiple frequency bands** designated for cellular services, providing flexibility to cover **two, three or even more bands**, with **different frequency ratios**

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Fractus's inventions provided the solution to that problem, and are now used nearly universally by carriers across the United States—and the world.

Fractus's patented base station antenna arrays allow for a single antenna array to operate at multiple frequency bands designated for cellular services, providing flexibility to cover two, three or even more bands, with different frequency ratios.

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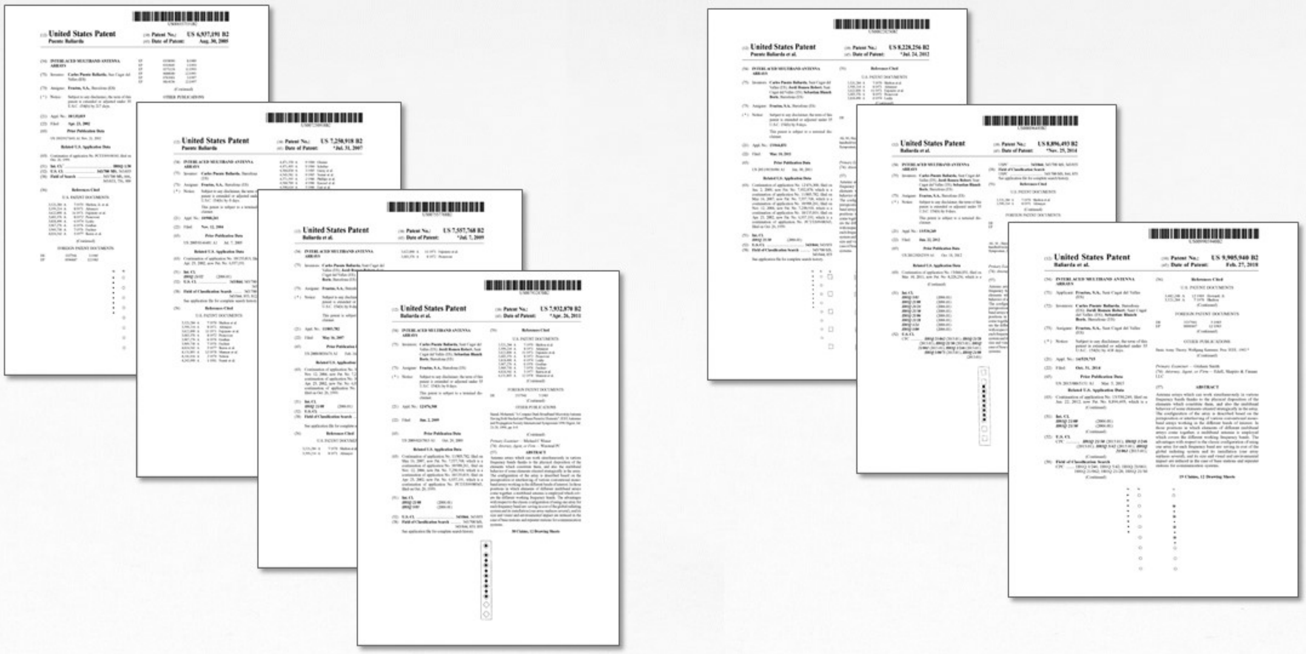
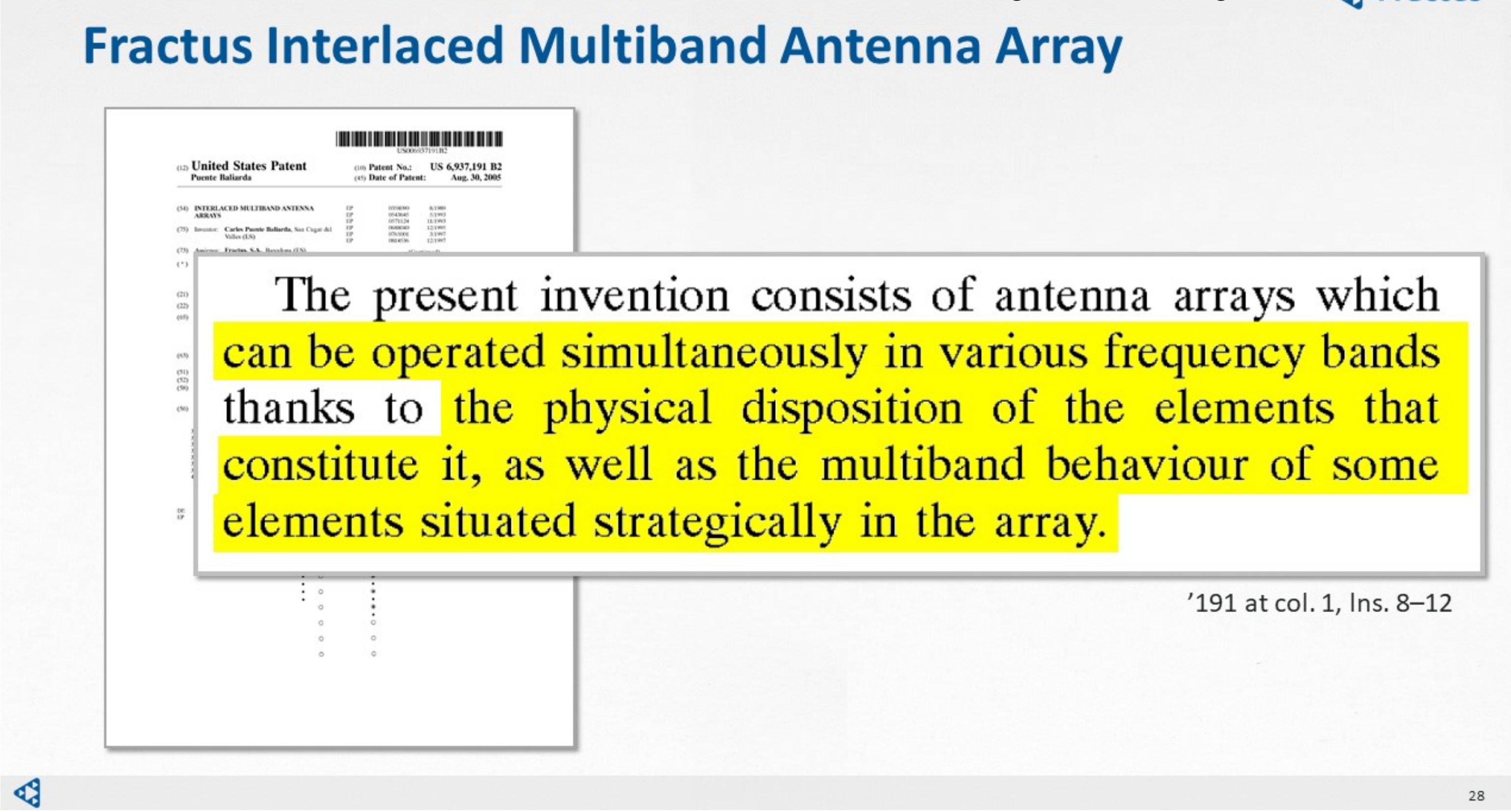
Fractus Interlaced Multiband Antenna Array

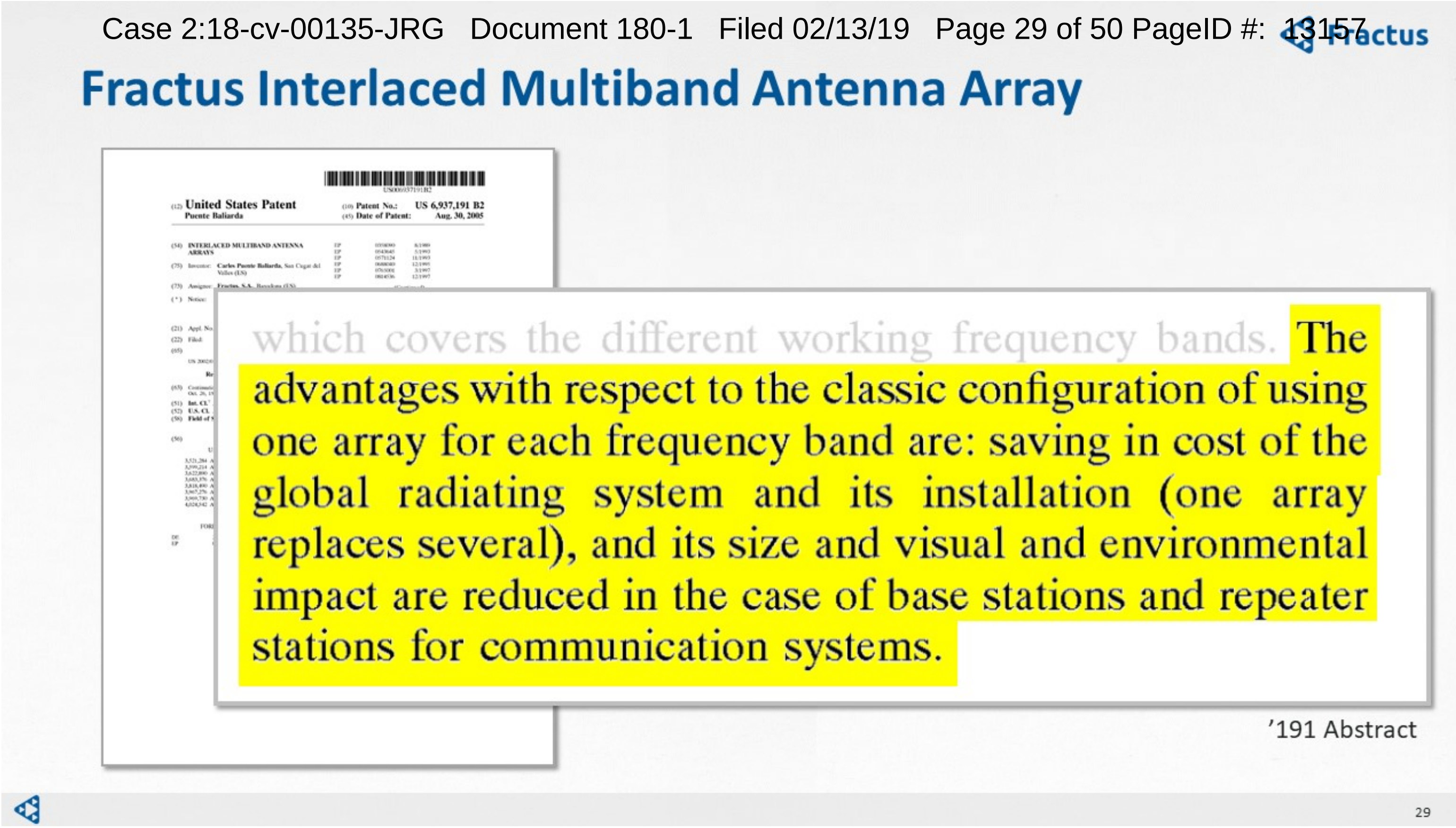


Fractus's foundational invention is disclosed and claimed in the first asserted patent family, seven of which are asserted here. Those patents, titled "Interlaced Multiband Antenna Array," are all based on same specification and claim priority back to an application filed in October 26, 1999.



Fractus' patented multiband antenna arrays are able to operate simultaneously on multiple frequency bands at the same time.

The invention is based on the strategic placement of multiband antenna elements in the array.



As stated in the patent itself, the advantages of the Fractus invention include “saving in cost of the global radiating system and its installation (one array replaces several), and its size and visual and environmental impact are reduced in the case of base stations and repeater stations for communication systems.” (’191 Patent, Abstract)

The Fractus invention is based on the strategic placement of multiband antenna elements in the array.

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Multiband Antenna Elements

(12) United States Patent
Puente Baliarda

(10) Patent No.: US 6,937,191 B2
(45) Date of Patent: Aug. 30, 2005

(54) INTERLACED MULTIBAND ANTENNA

The technology of individual multiband antennas is markedly more developed. A multiband antenna is understood to be an antenna formed by a set of elements coupled to each other electromagnetically which interact with each other in order to establish the radio-electric behaviour of the antenna, behaviour which with respect to radiation and impedance patterns is similar in multiple frequency bands (hence the name multiband antenna). Numerous examples of multiband

’191 at col. 2, lns. 32–39

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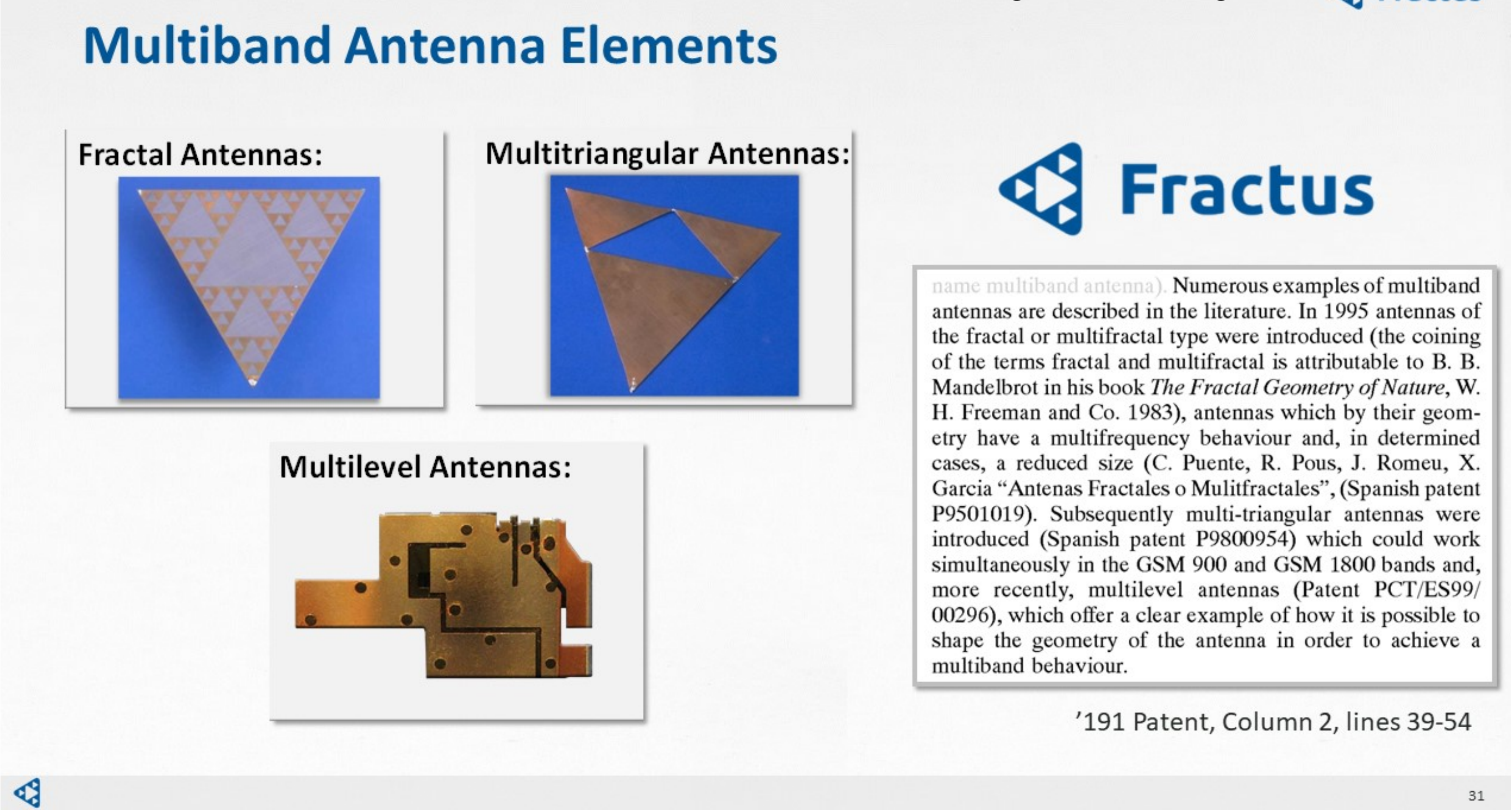
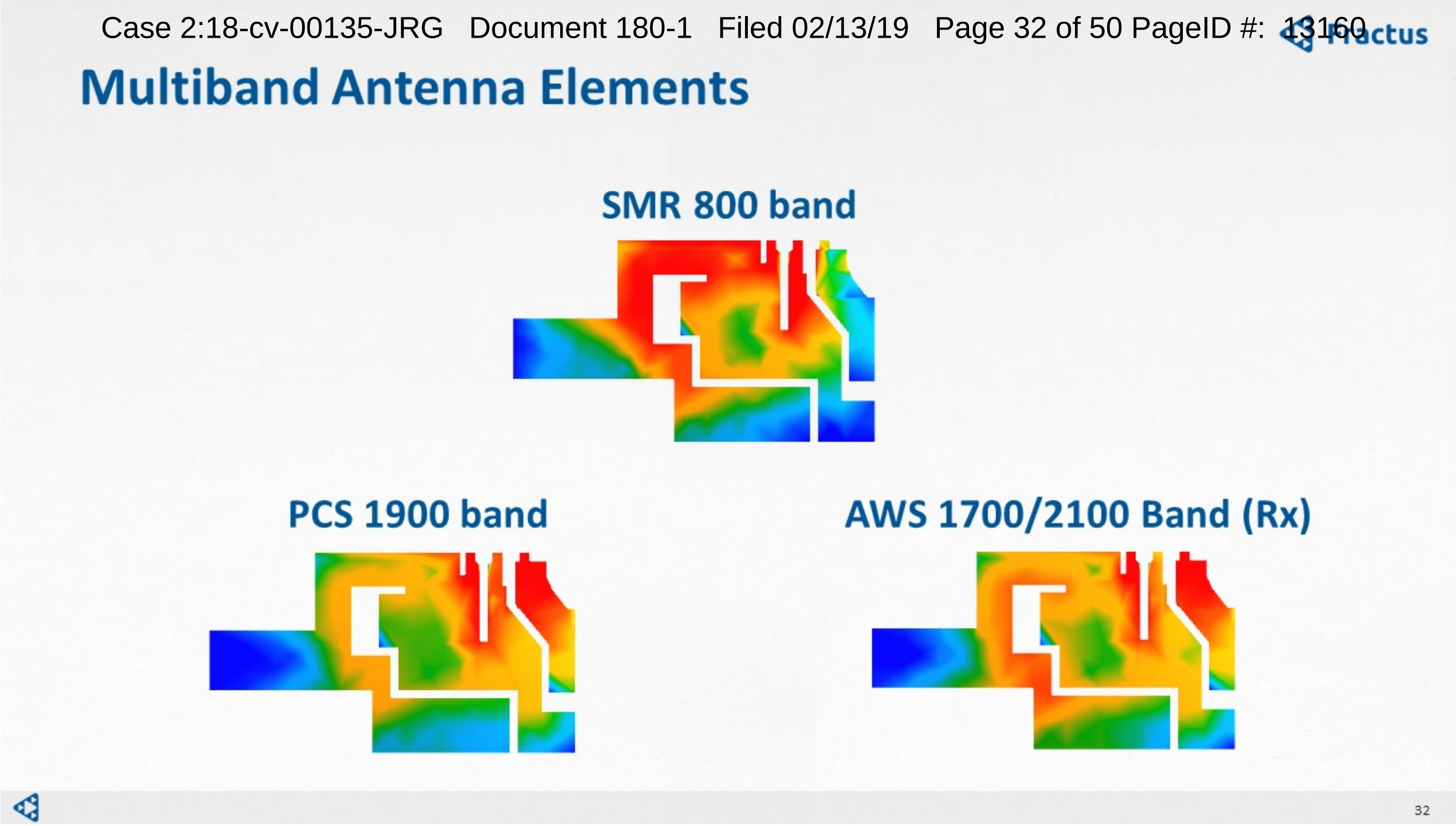
The Interlaced Multiband Antenna Array patents define a multiband antenna—which, in the context of an antenna array, is one of the elements of an array. It says: “A multiband antenna is understood to be an antenna formed by a set of elements coupled to each other electromagnetically which interact with each other in order to establish the radio-electric behaviour of the antenna, behaviour which with respect to radiation and impedance patterns is similar in multiple frequency bands (hence the name multiband antenna).”



Fractus's insights were based in part on the company's pioneering work developing new types of multiband elements—including those cited as examples in the Interlaced Multiband Antenna Array patents.



The multiband properties of multiband antenna elements result from their geometries. Current flows through different paths of the antennas, resulting in resonance at difference frequencies. As shown here in simulations for Fractus multilevel antennas, current flows through different portions—some of which may overlap—to provide operation at the different frequency bands. These varying current paths provide resonances at both larger and smaller frequencies resulting in multiband behavior.

In contrast, some prior art solutions utilized separate monoband elements located at the same position. Such configurations required additional structures to prevent the two from coupling, or interference. Such solutions did not provide adequate performance or flexibility. In contrast, Fractus' experience developing true multiband antennas led them to embrace coupling, and antennas where the different portions of the antennas worked together to provide the desired performance characteristics.

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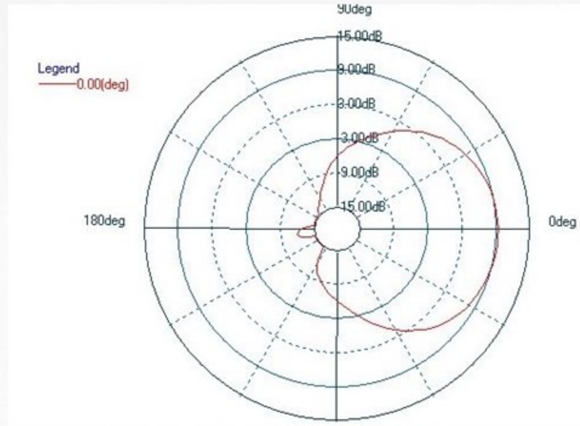
Multiband Antenna Elements

Impedance

Radiation



In addition to electromagnetic coupling, the patents define multiband antenna elements by reference to their performance in multiple frequency bands, specifically, that they have similar radiation patterns and impedance in multiple frequency bands.

As described above, these characteristics describe radiation shape and matching of the antenna to different frequencies. In a multiband antenna, those characteristics are similar in the desired frequency bands, allowing them to perform well in each band.

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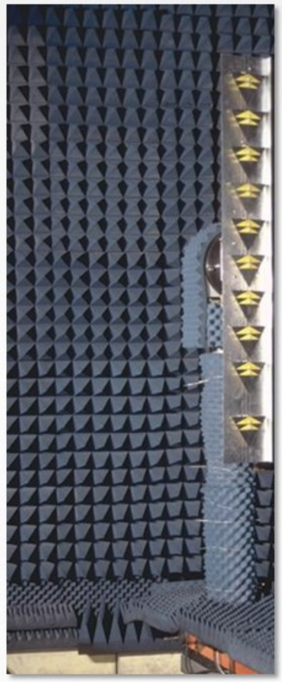
Multiband Antenna Elements



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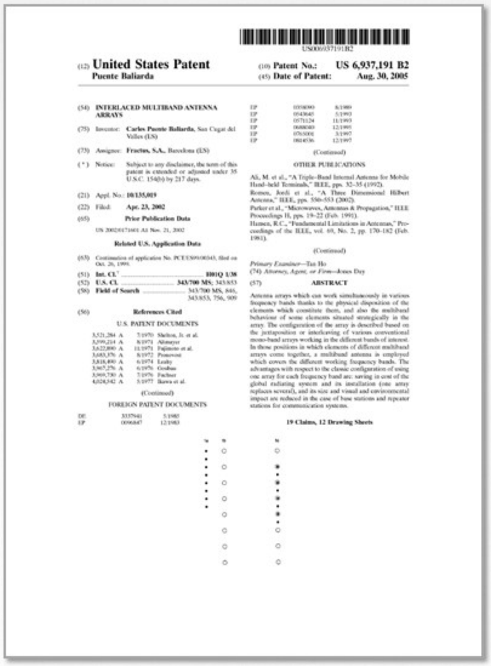
But even with that insight, applying it in the context of antenna arrays remained an unresolved problem.

Simply replacing monoband elements of a base station array with multiband elements is not an appropriate solution because in an array, the *spacing* of the elements is critical to performance of the array, including establishing the desired shape of directional radiation pattern.

Fractus overcame those engineering and physics challenges, and invented an array that was capable of operating in multiple frequency bands through the strategic placement of multiband elements in the array.

Strategic Positioning of Multiband Elements



A Multiband Interleaved Array (MIA) consists of an array of antennas which has the particularity of being capable of working simultaneously in various frequency bands. This is achieved by means of using multiband antennas in strategic positions of the array. The disposition of the elements that constitute the MIA is obtained from the juxtaposition of conventional mono-band arrays, employing as many mono-band arrays as frequency bands that it is wished to incorporate in the Multiband Interleaved Array. In those positions in which one or various elements originating in the conventional mono-band arrays coincide, a single multiband antenna (element) shall be employed which covers simultaneously the different bands. In the remaining non-concurrent positions, it can be chosen to employ also the same multiband antenna or else recur to a conventional mono-band antenna which works at the pertinent frequency.

’191 at col. 2, ln. 58 – col. 3, ln. 6

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The Fractus Interlaced Multiband Antenna Array patents detail the strategic positioning of multiband elements in arrays operating at different frequency bands—including those not conveniently related by an integer factor—including two, three or even more bands.

The patents use the term “juxtaposition” to describe the positioning of multiband elements in the interlaced multiband array.

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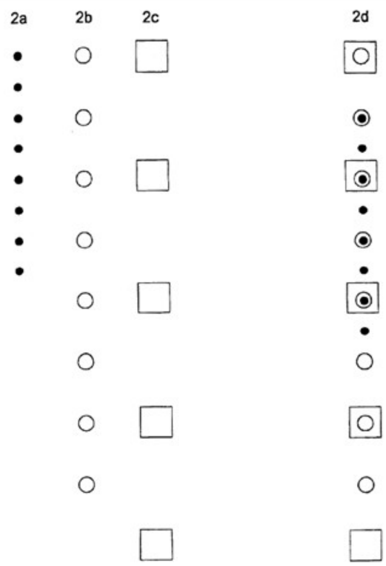

FIG. 2

squares respectively. The position of the elements of the MIA is determined from the configuration of the three mono-band arrays designed for each one of the three frequencies. The three arrays come together in the MIA that is shown in figure (**2.4**). In those positions where elements of the three arrays would come together (indicated in the drawing by the juxtaposition of the different geometric figures identifying each array) use is made of a multiband element. The three-frequency array of figure (**2.4**) behaves in the same manner as the three arrays (**2.1**), (**2.2**) and (**2.3**) at their respective working frequencies, but employing only 13 elements instead of the 21 required in the total of the three mono-band arrays.

’191 at col. 5, ln. 62 – col. 6, ln. 7

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The strategic positioning of the multiband elements in the array is determined by reference to the monoband arrays that correspond to the desired working frequencies at which the multiband array will operate. As the specification describes, conventional monoband arrays usually work within a relatively small frequency range, typically on the order of 10% about a center frequency. They are designed with a consistent spacing between the elements of around half a wavelength, but never more than one wavelength to avoid diffraction or grating lobes.

The positioning of elements in three such monoband arrays is shown in Figure 2, shown here, at 2a, 2b and 2c. In this example, the frequency covered by 2a is twice that of 2b, and the frequency of 2b is twice that of 2c. Therefore, the wavelength corresponding to the frequency for 2a is half that of 2b, and the wavelength corresponding to the frequency for 2b is half that of 2c.

Juxtaposition of the arrays is illustrated in Figure 2d. By juxtaposing (also called interleaving or interlacing) the three arrays—that is, by overlapping them to determine the positioning of the elements within them—locations on the arrays where the monoband elements come together (here indicated by the positions where the dot, circle and/or square are in the same position) a multiband element is used.

As the patent explains, the strategic placement allows the single array to operate on all three frequency bands, and also using lower number of total elements.

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FIG. 7

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Note that the term “interlaced” as used in the Interlaced Multiband Antenna Array Family does not mean that the multiband elements alternate with monoband elements, though that is one arrangement that is possible. Interlacing refers to the juxtapositioning of the monoband arrays, with the various monoband elements used to determine the positioning of the multiband elements in the resulting array.

The specification makes clear that *all* of the elements may be multiband elements, stating that after placing multiband antennas in positions where the conventional monoband elements coincide, that “In the remaining non-concurrent positions, *it can be chosen to employ also the same multiband antenna* or else recur to a conventional mono-band antenna which works at the pertinent frequency.” [CITE]

That configuration is shown, for example, in Figure 7 of the drawing, which shows one preferred embodiment, namely, an array using identical multiband antenna elements in each position of the multiband array.

Strategic Positioning of Multiband Elements

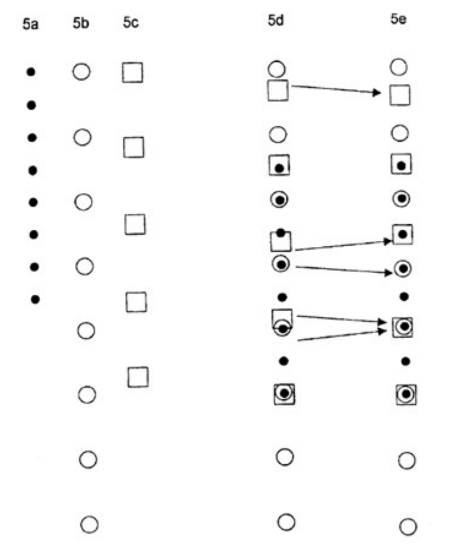

FIG. 5

In some configurations of multiband interleaved array, especially in those in which the different frequencies do not correspond to an integral factor of the highest frequency **1**, it is required that the elements be repositioned, as in FIG. **5**. In this particular example the frequencies f, f/2 and f/2,33 have been chosen. The disposition of elements of the three classic mono-band arrays at the frequencies f, f/2 and f/2,33 is represented in figures **(5.1)**, **(5.2)** and **(5.3)** by means of black circles, circumferences and squares respectively. The column of figure **(5.4)** shows what would be the disposition of elements in the tri-band interleaved array according to the same plan as in the previous examples. Notice how in this case the ratio of frequencies involves the collation of elements at intermediate positions which make its practical implementation difficult. The solution to be adopted in this case consists in displacing the position of the element of the array that works at the lowest frequency (indicated by arrows) until it coincides with another element (that nearest) of the highest frequency array; then the two or more coincident elements in the new position are replaced with a multiband element. An example of the final configuration

'191 at col. 6, ln. 67 – col, ln. 19

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While the process described above can be used to determine the position of elements when the wavelengths corresponding to the frequency bands covered by the multiband antenna array are related by integer ratio—for example, 2:1 or 3:1—when they are not then the specification provides guidance on how the elements in the juxtaposed monoband arrays should be repositioned to determine the correct location.

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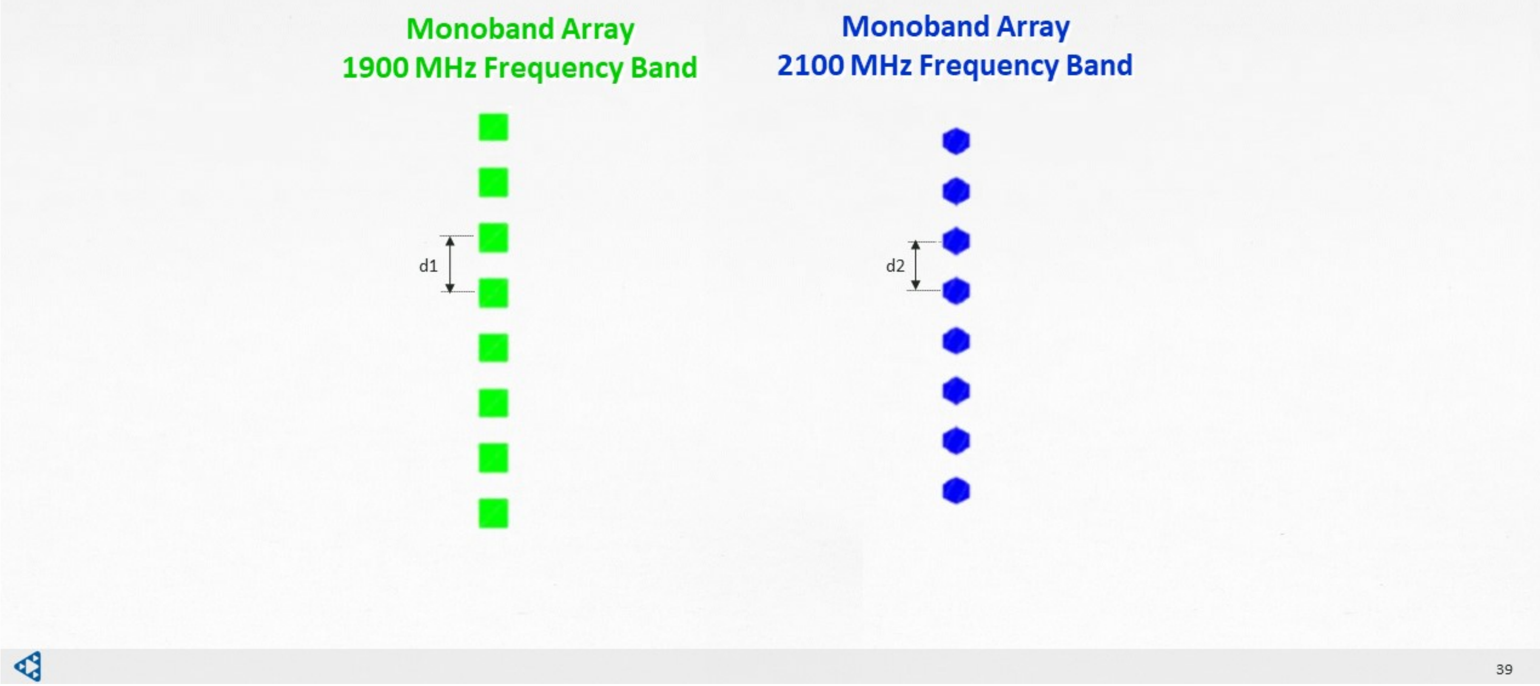
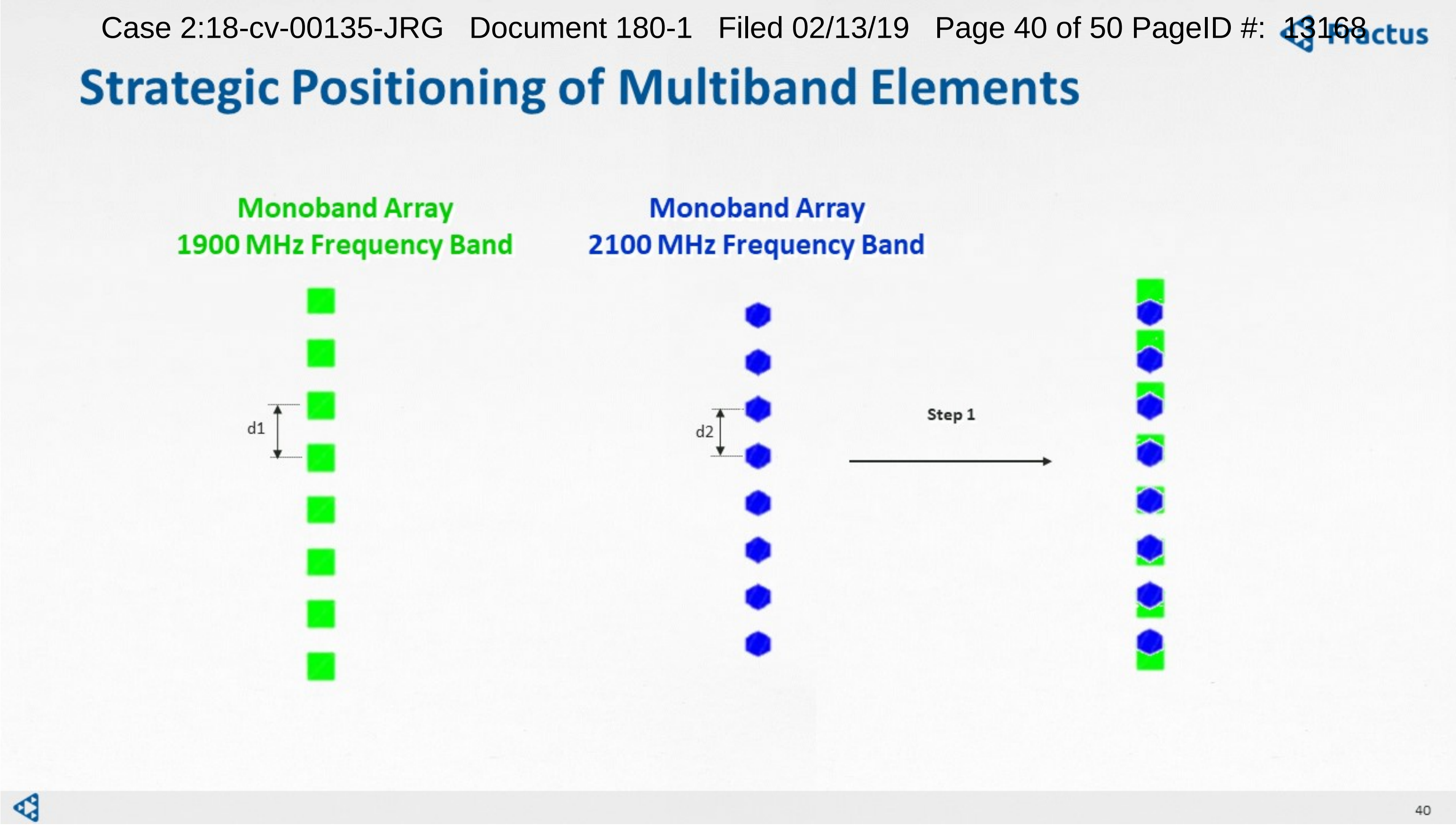
Strategic Positioning of Multiband Elements



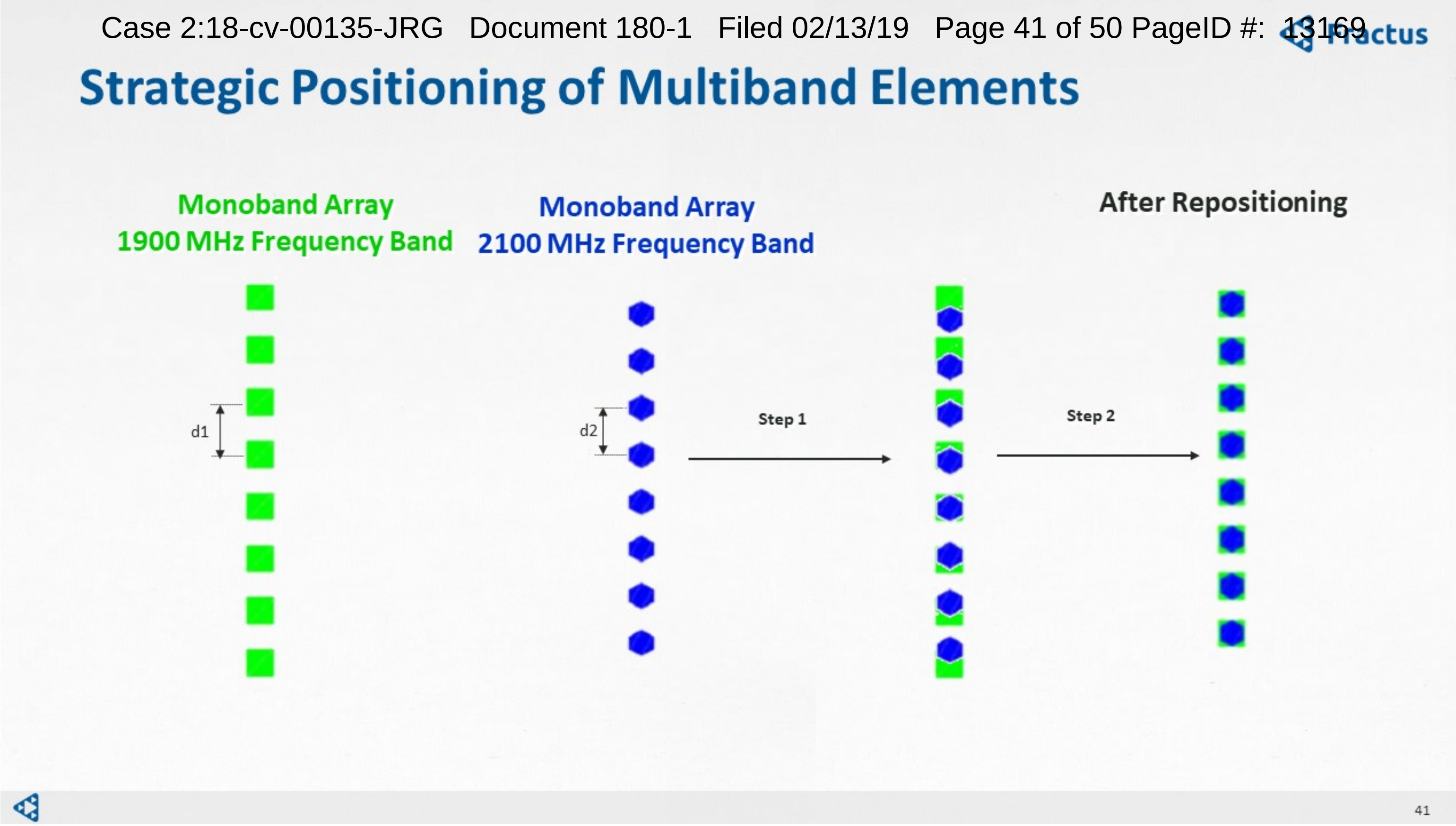
Shown here are diagrams showing the placement of antenna elements in two monoband arrays.

The diagram on the left in green shows the distribution of monoband elements in an array for operation in the 1900 megahertz frequency band. The distance between the elements is marked d1.

The diagram on the right in blue, a monoband array is shown for operation in the 2100 megahertz frequency band. Note that the distance between the elements in this array, marked d2, is smaller than the distance between the elements in the monoband array for the 1900 band, corresponding to the smaller wavelengths for frequencies in the 2100 band.



Shown here is the first step of the juxtapositioning process, described in the ’191 patent at, Colum 5 line 1 through Column 6 line 65. As is often the case when the ratio between the frequencies is not an integer, the monoband elements do not coincide in the same position, the patent describes a second step—repositioning—to determine the positioning of the multiband elements.



The patents direct that in such circumstances, the location of the multiband elements is to be determined by relocating the monoband elements so that they coincide and can be used to ascertain the correct position of the multiband element.

Shown here on the right is a diagram indicating the positioning of the multiband elements following repositioning.

Strategic Positioning of Multiband Elements

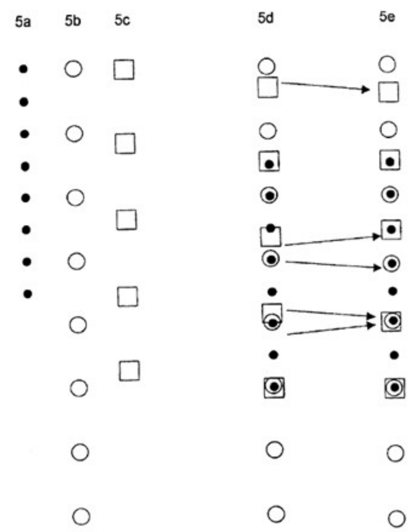


FIG. 5

implementation difficult. The solution to be adopted in this case consists in displacing the position of the element of the array that works at the lowest frequency (indicated by arrows) until it coincides with another element (that nearest) of the highest frequency array; then the two or more coincident elements in the new position are replaced with a multiband element. An example of the final configuration

’191 Patent, col. 7, lns. 12–19

The patents provide specific guidance as to the positioning of the relocated monoband elements, namely, by “displacing the position of the element of the array that works at the lowest frequency (indicated by arrows [in Figure 5, which is set out here]) until it coincides with another element (that nearest) of the highest frequency array; then the two or more coincident elements in the new position are replaced with a multiband element.”

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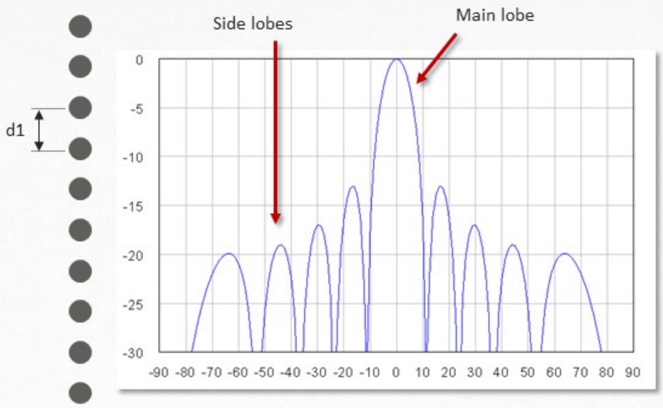
Strategic Positioning of Multiband Elements

"It is important that the element displaced, be preferentially that of the lowest frequency array, in this way the relative displacement in terms of the working wavelength is the least possible and the appearance of secondary or diffraction lobes is reduced to the minimum." ('191 Patent, col. 7, lns. 21–25)

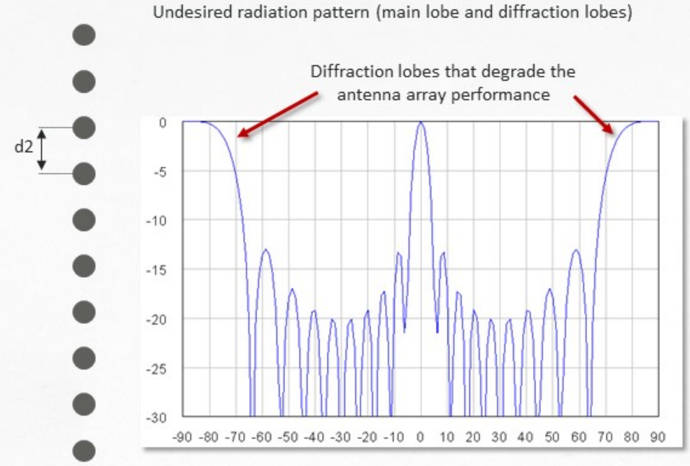
Proper Spacing of Elements

Desired radiation pattern (main lobe and no diffraction lobes)



Improper Spacing of Elements

Undesired radiation pattern (main lobe and diffraction lobes)



As the patents explain, the element to be relocated should be that of the lowest frequency array, because doing so will result in the least displacement, relative to wavelength. As a result, the desired radiation pattern will be maintained, and undesirable secondary or diffraction lobes will not appear.

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Repositioning

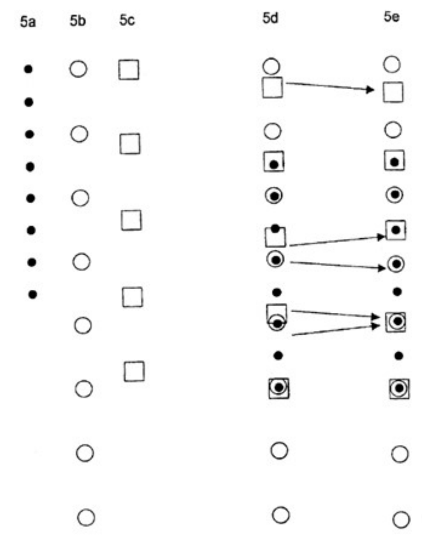

FIG. 5

FIG. 5 shows a multiband interleaved array configuration which requires a repositioning of the elements to obtain frequencies that do not correspond to an integer factor of the highest frequency. In this particular example the frequencies f, f/2 and f/2,33 have been chosen.

’191 Patent, col. 3, lns. 39–43

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As is shown in Figure 5 of the patents, repositioning provides direction to a person of ordinary skill in the art as to the positioning of multiband elements in an array covering three different frequency bands, even when—as shown here—the ratio between the frequencies is not an integer.

The Fractus interlaced multiband base station arrays can therefore be used to cover the real-world frequency bands allocated for cellular communications, most of which do not use frequencies at an integer scale factor.

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Dual Polarization

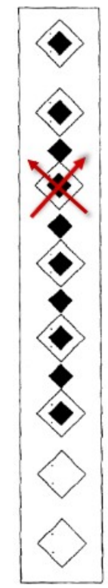
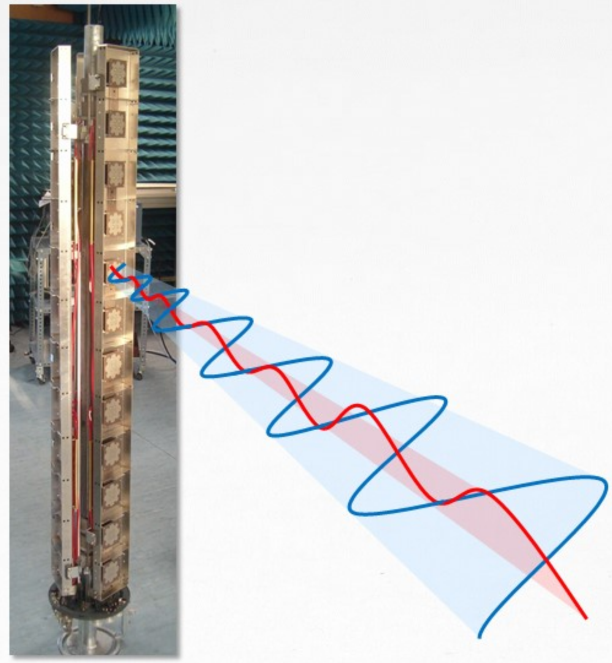
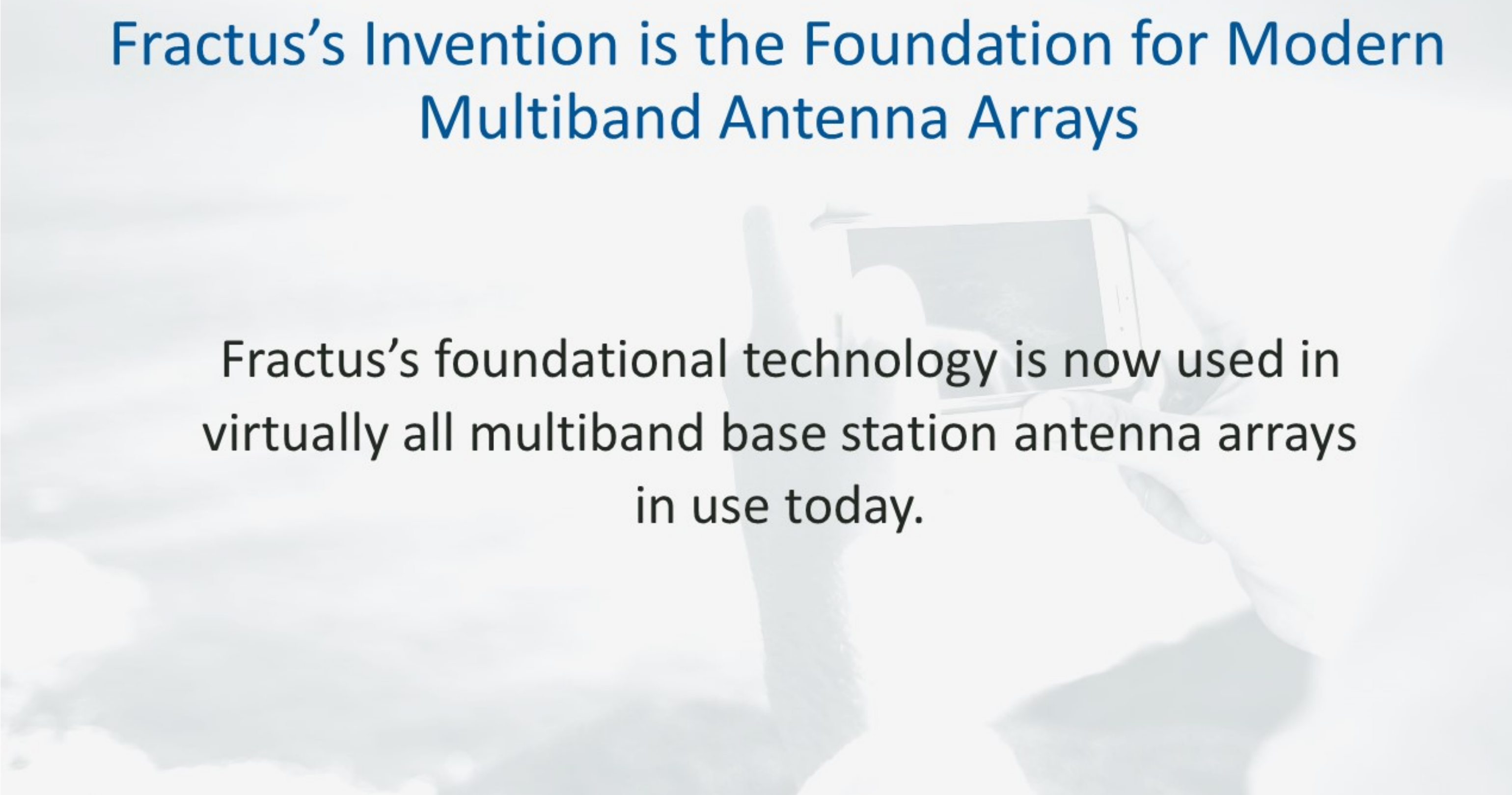


FIG. 12



As described in various preferred embodiments, including that shown here in Figure 12, the Fractus interlaced multiband base station arrays can include dual-polarized antenna elements. Dual polarization means that the radio waves are radiated in two different directions, commonly at orthogonal angles to each other and typically in cellular systems at 45 degree angles from the vertical axis. Use of dual polarization increases the capacity which results in an improved performance and efficiency of the base station, by using the same spectrum.



Fractus's foundational technology is now used in virtually all multiband base station antenna arrays in use today.

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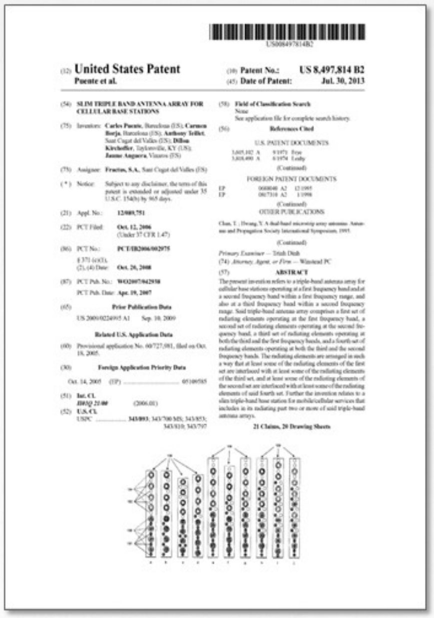
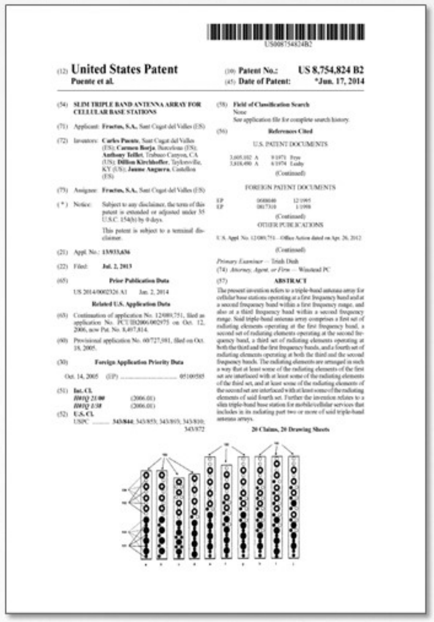
Slim Triple Band Antenna Array for Cellular Base Stations





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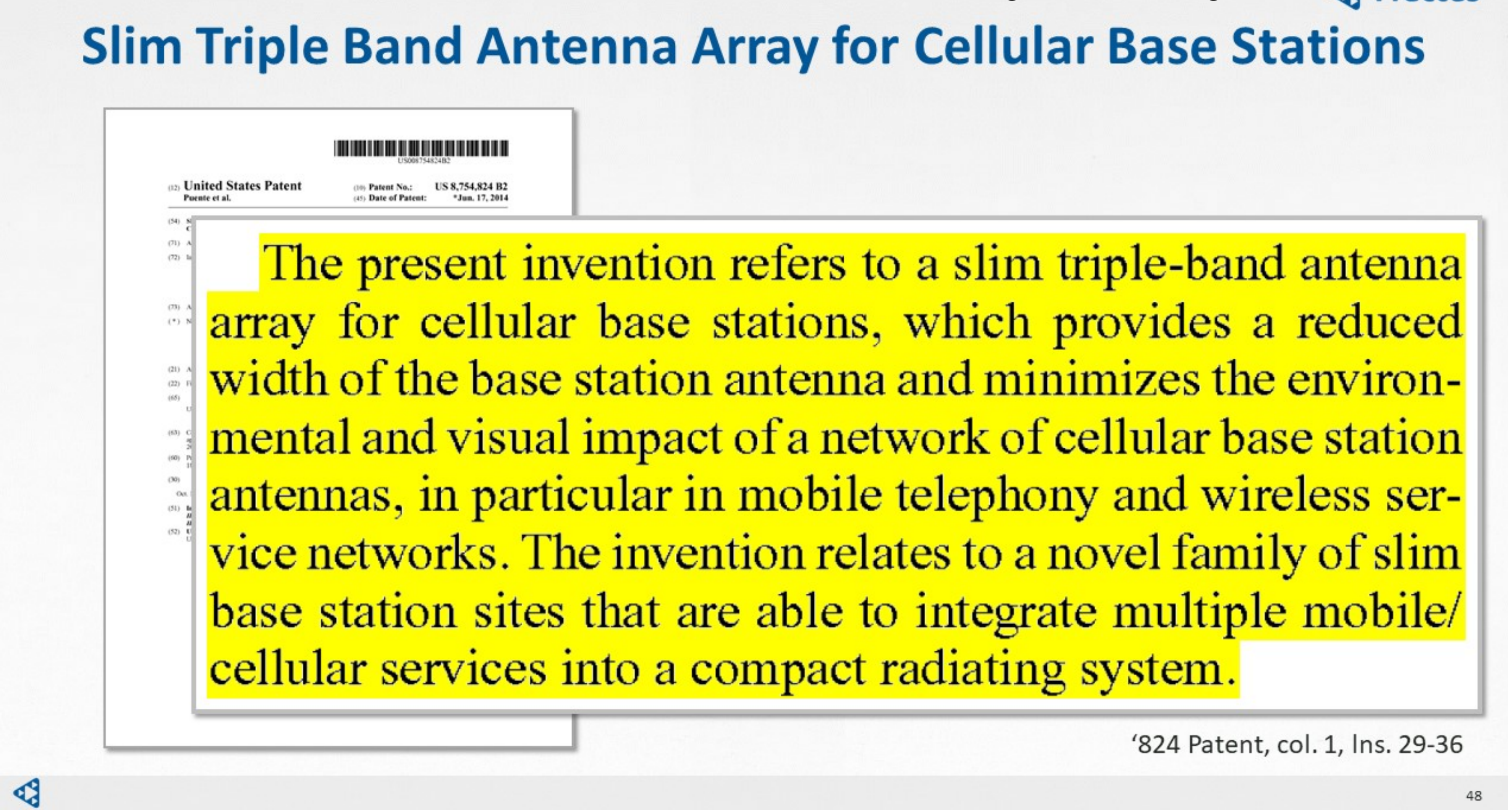
The second family of patents-in-suit reflect Fractus's further development of multiband technology, which allowed for the further reduction in size while integrating additional features that add to the performance of base station antennas.

The patents are titled "Slim Triple Band Antenna Array for Cellular Base Stations." Two patents from the family are asserted here. All are based on same specification and claim priority to applications filed in October 14, 2005.



The slim triple band family builds on the technology claimed in Fractus's interlaced base station antennas, providing further refinements allowing for more compact antennas capable of operation on three or more frequency bands.

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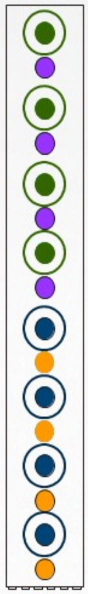
Slim Triple Band Antenna Array for Cellular Base Stations



Positions in the triple band array for the **second set radiating elements** operating at the ***second frequency band***

Positions in the triple band array for the **fourth set of radiating elements** operating at the ***second frequency band*** **and third frequency band**

Positions in the triple band array for the **first set of radiating elements** operating at the **first frequency band**

Positions in the triple band array for the **third set of radiating elements** operating at the **first frequency band and third frequency band**

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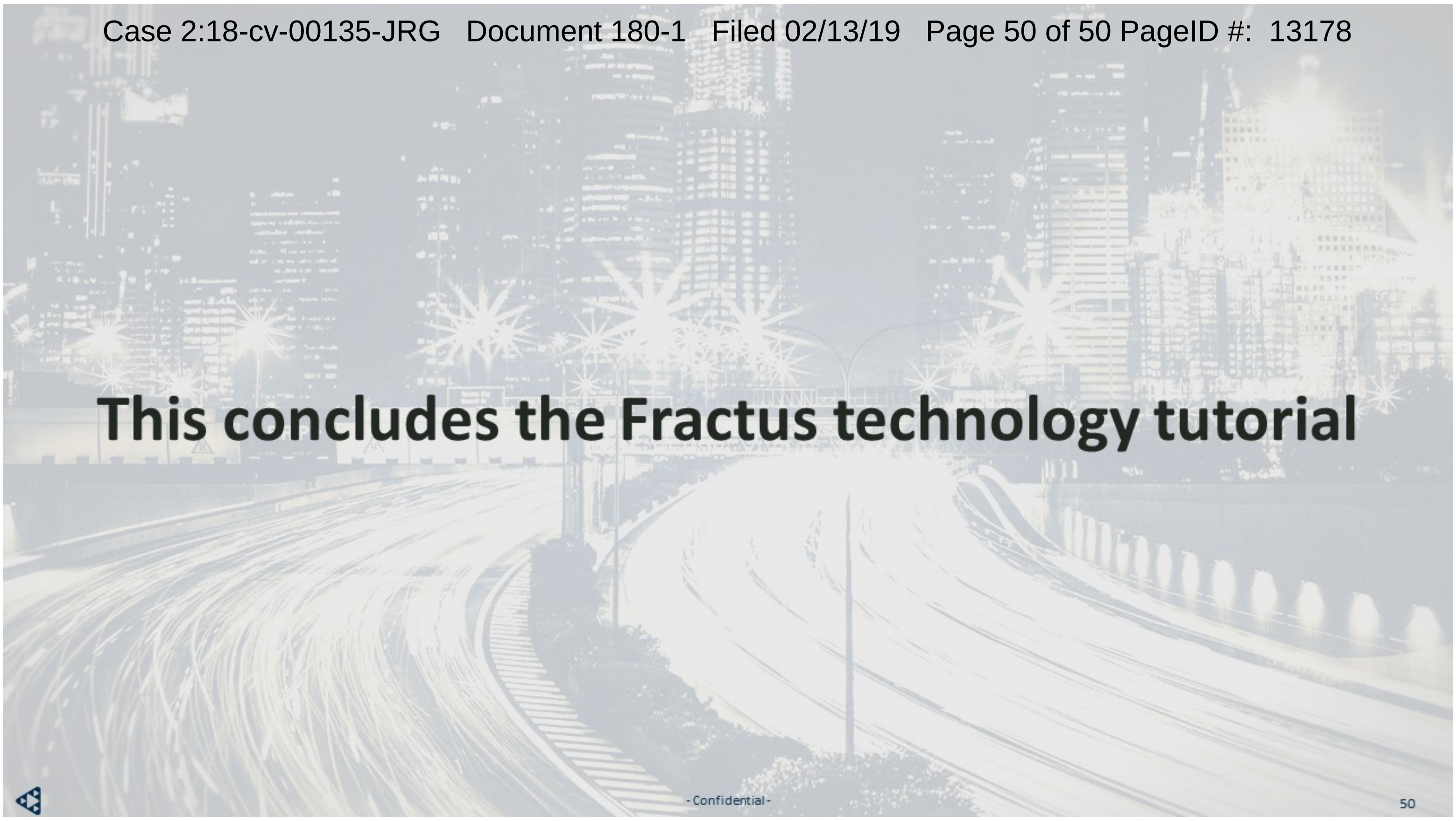
In the example shown on the left, the slim triple band patents claim a configuration of elements that combine operation in each of the covered bands. Those shown in the blue dots and circles, for example, operate in the first and third bands, while those shown in the green dots and circles operate in the second and third frequency band.

By use of these configurations, Fractus was able to develop base station antennas of further reduced size, leading to additional cost savings for mobile network operators.



This concludes the Fractus technology tutorial